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SOME ASPECTS OF AQUACULTURAL ENGINEERING IN JAPAN

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ABSTRACT

The technology of culture of marine organisms includes production of seeds of cultivable organisms in hatcheries, nursery rearing, stocking in ponds and culturing them to harvestable size. In recent years special environments such as releasing sites for Kuruma-shrimp (*Penaeus japonicus*) juveniles, abalone juveniles, reclamation of kelp ground in the sandy beaches and nursery grounds for abalones or sea-urchins have been developed. Techniques of controlling dispersion of larval stages of shell-fishes have also been evolved.

Aquaculture engineering involves mainly consideration of two aspects, namely, design of facilities and preservation of water quality. In open sea farming, factors such as wave force, current pattern and flow of water are to be taken into consideration while designing the culture structures like fish retention nets, rafts and mooring ropes. To safeguard these structures from wave force, different types of wave attenuators such as the gravity-type dyke, submerged dyke, floating wave attenuator and pneumatic wave attenuator have been developed. To ensure the quality of water, its exchange and circulation in the culture area, improved tidal inlets, waterways on flat shores and training dykes have been designed. The problems of aquaculture engineering and the recent advances made in this direction are discussed in the paper.

INTRODUCTION

JAPANESE AQUACULTURE can be divided into two : enhancement of marine life and farming. Marine life may be enhanced by cares taken by human beings which affect some parts of its reproductive processes.

One of the enhancing methods is nursing of juveniles, that is, the juveniles, from gravid females caught or collected from the sea, are protected in a laboratory for an adequate period. After protection, the juveniles are released into the natural sea. The other method is to control the environment, that is, constructing a nursery, for example, that promotes the survival rate of juveniles.

Enhancement by controlling the environment has been undertaken by regional governments or fisheries cooperatives, and from 1969, the Fisheries Agency was also involved.

FACILITIES FOR ENHANCEMENT

Releasing sites for Kuruma-shrimp juveniles (Penaeus japonicus)

Figure 1 shows an artificial tideland for shrimp seed. The juveniles of the shrimp grow, in about 40 days after hatching, to 10 mm body length. During this time, they are pelagic, so that they can be reared on a massive scale of the order of some thousands of millions.

When over 10 mm in size, they are released into natural tideland where they encounter terrible predators and severe effects of waves or tidal current. The mortality rate soon after release is so large that they hardly survive. The survival rate being of the order of a few per cent.

Artificial tideland is intended to promote the survival rate of the juveniles soon after release. A field test had been performed in an artificial tideland of 0.6 ha. The test was aimed to analyse the factors relevant for the survival of the juveniles.

The tideland was divided into 12 basins and 50 factors were investigated. As a result of this, one important factor was isolated and that was the unsuitable condition for a predator, goby. Considering the result, another tideland was constructed (Fig. 1).

while in an ebb tide it changes to a shallow pool of about 5 cm in depth.

It kept the short term density of the juveniles at 100-130/m^2 and the survival rate at more than 80%. The released juveniles grow to 30 mm in body length in about 2 weeks and gradually move to deeper waters.

Releasing sites for abalone juveniles

In the case of abalone, the juveniles are often discovered in a gravel bed at the surf zone. Such a habitat can be constructed by rip-rap with a wire-net (Fig. 2) or precast concrete frame work that holds the rip-rap still under severe wave action. The artificial seeds of 20 mm size are released in it.

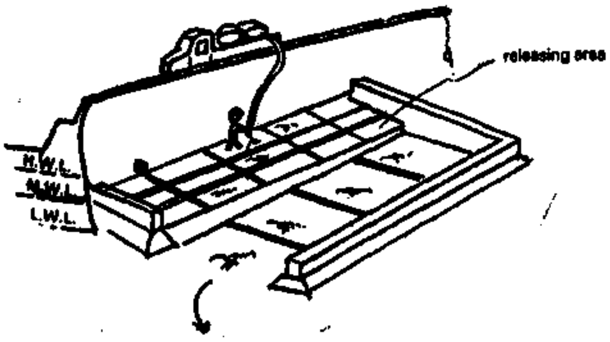

Fig. 1. Artificial tideland for shrimp seed.

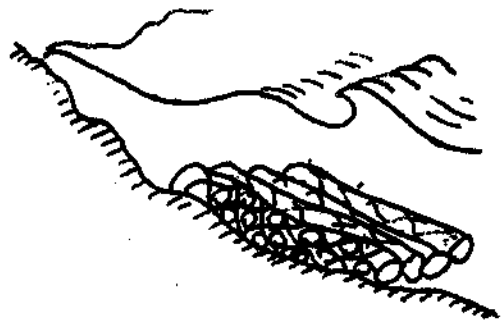

Fig. 2. Habitat for abalone juveniles.

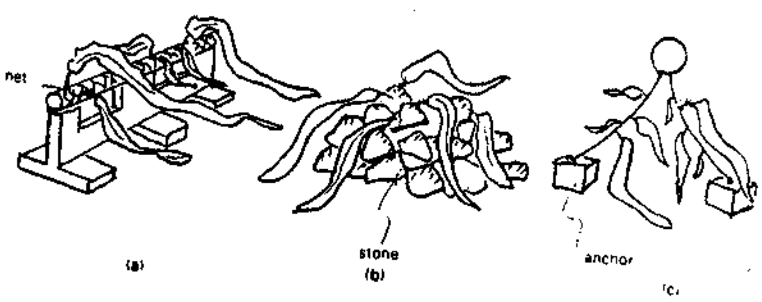

Fig. 3. Attachment bases for kelp.

This tideland of 2.4 ha (1 ha of releasing area and 1.4 ha of interim growth area) has a submerged dyke that prevents sand drift caused by wave action, but has no enclosure for animals. In a flood tide, it is fully submerged,

Reclamation of kelp ground from sandy beaches

Figure 3 shows the facilities for kelp enhancement. Kelp is used as a food for human beings and for abalone or sea-urchin. As kelp needs an attachment base, the facilities consist of the attachment bases, such as precast concrete, gravel, synthetic material, etc.

Nursery grounds for abalones or sea urchins

The nursery requires sea weed as food. As attachment bases for animals, concrete blocks, rip-rap or synthetic materials are also used. Figure 3 (c) shows the one for feeding abalone or sea urchin. Kelp seed is attached to a rope kept afloat by a buoy and animals are prevented from eating up the plant in its early stages. When the plant has sufficiently grown, the rope is pulled down by the weight of the plant and the animals can feed.

Nursery ground for young file fish

Figure 4 shows a cross-shaped concrete block for young file-fish. Positioned in a stream, this structure can change the flow velocity. With the structure set so as to intensify the flow velocity, the sand bed is

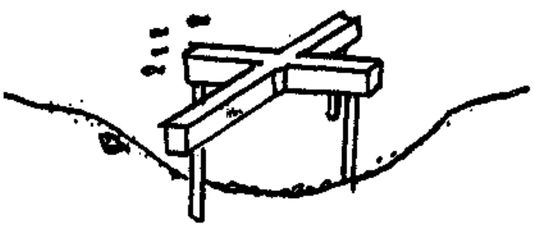

Fig. 4. Improvement in sea bed for young file fish

removed and a trough with gentle slope is resulted under the structure. Such a trough is suitable for young file-fish as a feeding area.

Dispersion control of larval stage of shellfish

Generally a marine organism spends its larval stage floating and the larvae are wholly transferred by current flows. This may result in a high mortality rate in that stage.

Figure 5 shows facilities that prevent offshore dispersion of shellfish larvae. The mechanism used is to promote circulation by means of shoaling wave energy. Circulation can be independent of the general flow and will prevent, if there are floating-stage juveniles in circulation, the dispersion of the juveniles without enclosure.

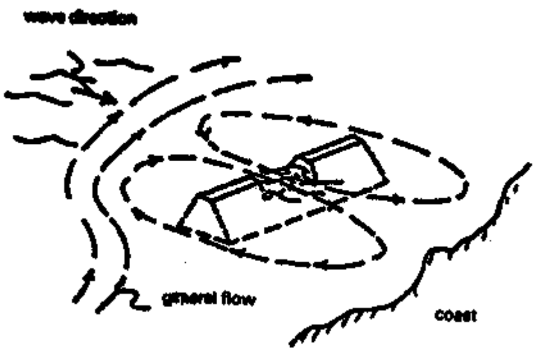

Fig. 5. Dispersion control by wave energy.

Facilities for Fish Farming

In principle, farming requires two aspects of engineering ; dynamics and preservation of water quality.

Aquacultural facilities, such as fish retention nets, rafts and mooring ropes, are designed for the expected wave force or flow.

As other facilities for culturing basins that preserve the aquacultural facilities from the incident waves and facilitate management, wave attenuators have been developed. These include the gravity-type dyke, submerged dyke, floating wave attenuator and pneumatic wave attenuator.

A mariculture is apt to contaminate the water. As the preservation of water quality requires both exchange and interchange of the waters. Figure 6 shows a fish farm enclosed by breakwaters and netting for yellowtail or sea-bream. Those parts of the enclosure, attacked by strong waves may be breakwaters, the other parts can be netting. The planner of the farm should take into account the interchanging of the sea water. As engineering items, improvement of tidal inlets, waterways on flat shores and training dykes are being designed.

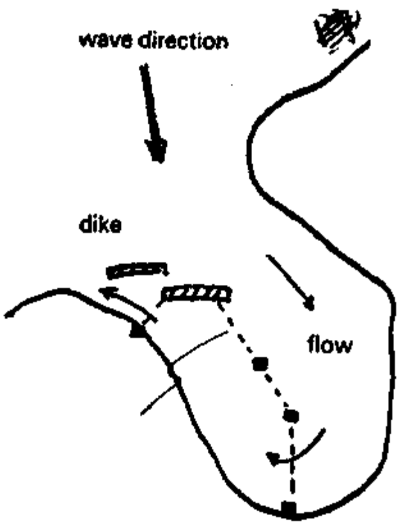

Fig. 6. Fish farm.

Aquacultural engineering also has many environmental problems related to physical aspects. The relation between physical aspects under water and behaviour of marine organism should be keenly investigated.

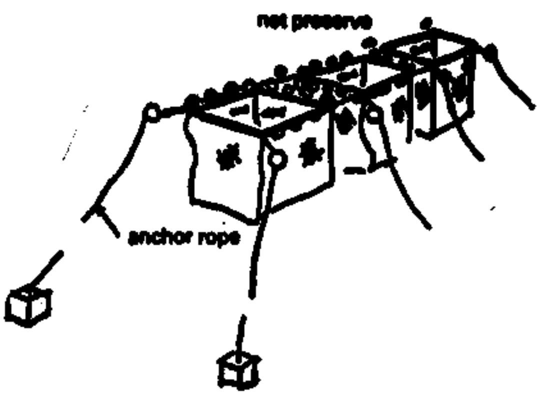

Fig. 7. Fish retention net.

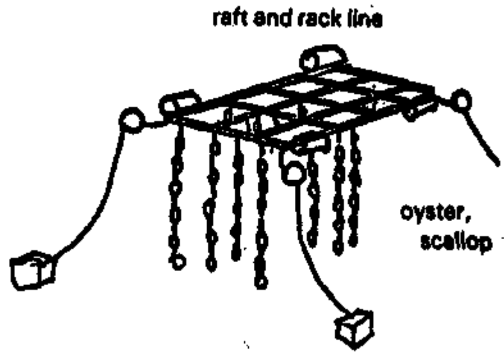

Fig. 8. Raft and rack line.

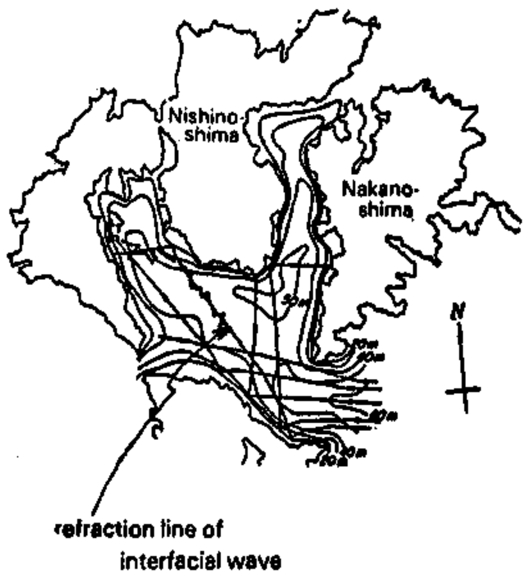

Fig. 9. Migration of sea bream and interfacial wave refraction.

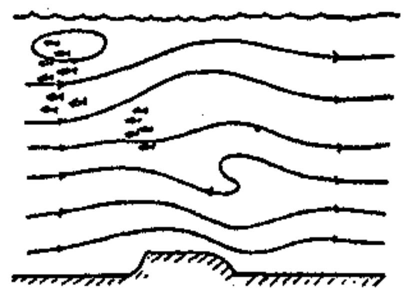

Fig. 10. Surface layer fish and lee wave.

Some examples shall be shown :

The relationship between a refraction diagram of an interfacial wave and sea-bream migratory path is shown in Fig. 9. The interfacial wave is seen in the boundary between the high and low density of waters caused by water temperature difference or salinity difference. A school of fish staying in the lee wave caused by the topography of the sea bed is shown in Fig. 10.

If the behaviour of marine organisms in relation to physical environment is understood, aquaculture with environment control has a promising future.

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STATUS OF COASTAL AQUACULTURE IN SINGAPORE

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Abstract

In addition to the general development on fisheries in Singapore, this paper briefly summarises the progress and problems of mariculture research and development as well as other areas of coastal aquaculture research *viz.*, (i) induced breeding, (ii) fish nutrition and feed development technology, (iii) fish pathology, (iv) harvest and processing technology for mussel and (v) environmental studies.

Introduction

Singapore is a small island state of 616 km^2 in area with a population of 2.33 million ; it is located in the centre of the Malayan Archipelago at the cross roads of the Pacific and Indian Oceans. Fish and fish products constitute an important component of the Singaporean diet. Per capita consumption of fresh fish alone is about 30 kg/year, representing 30% of the total animal protein intake (Chen *et al.*, 1977). However, its fishing industry is small and its domestic fresh fish demand is met by import amounting to about 75%, mainly from its neighbouring countries in Southeast Asia. Being a geographically disadvantageous state within the context of the new sea regime, the prospect of further expansion of its capture fisheries sector is not encouraging. Other factors limiting its growth include the increasing fuel cost and the strong competition for labour and capital from other sectors of the national economy.

Rationale for Coastal Aquaculture Development

Aquaculture production in Singapore is about 1% of its annual fresh fish consumption of 65,000 tonnes. Fish farming operations are mostly confined to the traditional Chinese pond method of composite culture of carps integrated with small family-holding type of agriculture and/or livestock husbandry. Penaeid shrimp production in coastal impoundments is also traditional and is entirely dependent on tidal movement for recruitment and harvesting. Such methods with little management have limited yield, averaging 2 tonnes/ha/year and 0.3 tonne/ha respectively in freshwater and brackishwater ponds. At present, there are about 325 ha of freshwater carp ponds and 375 ha of brackishwater shrimp trapping impoundments, but rapid economic growth and urbanization have rendered these traditional practices uneconomical in land-scarce Singapore. High priority has now been placed on the development of intensive and economically viable aquaculture systems aimed at optimum production and economic returns per unit area or effort. Besides other factors, high cost of land and competitive demand by various sectors of the economy have created the need to develop coastal aquaculture to supplement its home-base fish production. It is therefore not by choice that Singapore looks towards its coastal waters for the development of mariculture.

Because of its inherent physical limitation and other economic development priorities, Singapore is not expected to achieve self-sufficiency in the supply of fresh fish to meet its domestic demand through mariculture. Fish import from its traditional fish exporting neighbours will continue to remain in its fishery supply scene. Singapore's effort in mariculture development is therefore aimed at establishing suitable technology for transfer not only to its fish farmers but also to supplement the efforts of its neighbouring countries. Excess mariculture production in these countries will always find a ready market in Singapore, thereby ensuring adequate fish supply to meet its domestic demand and further strengthening the regional aspiration of cooperation for mutual benefit.

Progress and Problems of Mariculture Research and Development

The limitation and high cost of land, water and labour in Singapore have provided the impetus to develop intensive marine fish farming systems with optimum utilization of space and manpower. Research and development programmes are being implemented to reflect a balance between economically viable production of inexpensive aquatic food organisms for the population at large and highly-priced food fish species for the luxury market. These systems presently receiving institutional attention are: (*a*) floating netcage culture of finfish and (*b*) floating suspended culture of mussel. Preliminary studies showed that production rates of 50 kg/m^3/year for grouper culture in floating cages and 120 kg/m^3/6 months for mussel culture could be achieved. These are in sharp contrast with the production rates of 0.2 kg/m^3/year for carp and 0.03 kg/m^3/year for shrimp obtained under the traditional pond system of fish culture.

The selection of fish species for culture is based on the following 3 principal criteria: (*a*) high market demand and/or value, (*b*) rapid growth under crowded and confined conditions and (*c*) adequate and regular supply of seeds either through controlled breeding under captive conditions or easily caught from the wild. Potential species which meet the above criteria in Singapore are the green mussels (*Mytilus viridis*) and the carnivorous finfish species such as the grouper (*Epinephelus tauvina*), sea perch (*Lates calcarifer*), golden snapper (*Lutjanus johnii*), mangrove snapper (*L. argentimaculatus*), red snapper (*L. altifrontalis*), threadfin (*Eleutheronema tetradactylum*), golden trevally (*Caranx speciosus*) and yellowfin jack (*C. ignobilis*).

Besides the development of these systems, other areas of research are : (*a*) induced breeding of marine finfish, (*b*) fish nutrition and feed development technology, (*c*) fish pathology, (*d*) harvesting and processing technology for mussel and (*e*) environmental studies.

Induced breeding

As Singapore has a small shelf area of about 700 km^2 and hence limited fisheries resources, the main constraint to mariculture development is the shortage and irregular supply of fish fingerlings. The major thrust of research has therefore been concentrated on the induced breeding of fish. It involves research into broodstock development and maintenance, hormone induced spawning, larval rearing and the culture of micro-organisms as larval food. Success has been achieved under laboratory conditions in the production of fingerlings for several marine species, including the protogynous hermaphroditic grouper (Chen *et al.*, 1977), golden snapper and rabbit fish. Hybridization between the estuarine grouper (*E. tauvina*) and the humpback grouper (*Cromileptes altivelis*) has also been achieved.

Initially, the grouper (*E. tauvina*) will be the target species of research and development of netcage fish culture. The progress and problems encountered have been reported by Chen (1979). Technology developed for the mass production of its fingerlings would serve as a model for other highly-priced marine food fishes. The construction of a pilot hatchery and nursery together with facilities for the culture of micro-organisms as live larval food will soon be completed. It will provide the essential facilities for the development of suitable methods for large-scale fingerling production of grouper as well as other identified marine food fish species.

Fish nutrition and feed development technology

The study on fish nutrition and the development of artificial feeds for marine carnivorous fish species has been initiated recently on an *ad hoc* basis. It is of high priority particularly with the development of intensive aquaculture systems in which space and labour are optimally utilized. It is aimed at resolving the problem regarding the seasonal and insufficient supply of 'trash fish' which could be utilized for direct human consumption. Progress has been satisfactory; laboratory-reared fingerlings of grouper, seaperch and snapper have been adapted to accept dry pelleted feed with promising growth rates and conversion ratios.

The use of artificially formulated diets provides better dietary control, makes storage, handling and feeding more convenient, minimises wastage and water pollution and allows for easy incorporation of additives as and when required. The successful development of this area of aquaculture would align fish farming with livestock husbandry. Plans are being formulated to develop facilities for this important area of work.

Fish pathology

Research into fish diseases is also conducted on an *ad hoc* basis. It involves the isolation and identification of pathogens, histopathology and chemotherapeutic and fish health management studies. Several cases of superficial lesions of vibriosis and gill infestations by monogenetic trematode (*Diplectanum* sp.) have been observed in grouper cultured in commercial farms.

Harvesting and processing technology for mussel

It has been shown that mussel as a source of rich but inexpensive animal protein has a great development potential in Singapore (Chen, 1977; Cheong and Chen, 1980). The main constraint to its large-scale development lies in the handling of large quantities of fresh shell-on mussels harvested at any one time. In the mussel producing countries in Europe, this problem has been resolved through mechanization. The machines developed include the declusterer and washer, debearder, desheller and brine-tank separator manufactured specifically for the European mussel (*Mytilus edulis*). To accelerate mussel culture development in Singapore, such facilities are being established to determine the suitability (with or without modifications) of such equipment for the mussel species (*Mytilus viridis*) occurring in the region.

Another aspect of post-harvest treatment is that of depuration. This operation is important for the fresh shell—on trade and research in this field should be enhanced to promote mussels, as well as other filter-feeding bivalve like oysters, cockles, clams, etc. as wholesome quality food. The dangers and repercussions of an incident reminiscent of the recent shellfish poisoning outbreak in the oyster industry in Australia would seriously undermine the thriving mollusc industry in the region. Chlorination and UV methods of treatment of seawater are being tested, including economic assessment.

Environmental studies

Coastal waters are subject to the influence of activity on land, river runoff and open sea water. The variations of environmental parameters with time and space in coastal waters are larger than in the offshore waters. Hence the organisms in the coastal waters have to survive the integrated effects of these rapid changes. For these reasons, environmental studies play an important role in mariculture development from the standpoint of production and engineering. Such studies have been included in the mariculture research programme in Singapore, especially in the identification of suitable areas for various mariculture activities, forecasting probable adversed condition and establishing guidelines for administrative and regulatory purposes.

From the above, it can be assessed that mariculture in Singapore is still in its initial stages of development. While several operators of palisade fish traps and coastal fishermen have gone into small-scale commercial production of marine finfish employing the netcage method and of mussel using the floating suspended method, it will be a few more years before a viable mariculture industry can be established in Singapore.

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U.S. AGENCY FOR INTERNATIONAL DEVELOPMENT STRATEGY FOR AQUACULTURE DEVELOPMENT

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ABSTRACT

Some key policies of the U.S. Agency for International Development that provide a framework for the aquacultural development strategy are reviewed and the resulting strategy is described. The approach encouraged by AID to benefit the poor in aquacultural development is outlined. New opportunities that can be used to insure that benefits reach the poor but that have not yet been widely utilized are discussed. Alternative approaches are considered and one is discussed.

INTRODUCTION

NO ATTEMPT is made here to review all U.S. Agency for International Development (AID) policies that impact on aquaculture projects. Instead, a few key policies that have major impacts on the type and structure of aquaculture projects funded by AID are examined. The approach used to carry these policies through to implemented projects is examined primarily so that other donors and development agencies can judge whether this approach is useful from their viewpoints to accomplish the objectives of their agencies or countries.

For purposes of discussion some suggestions for increasing the involvement of the poor in aquaculture are reviewed. Although most of these methods have been tried at some time under limited circumstances, it is proposed that they be tested further under a wider range of circumstances.

KEY USAID POLICIES

Six statements are listed below which reflect the primary interests and direction of AID policies regarding aquaculture.

— There is a recognition within AID that fish production is an important means of increasing production of animal protein.

— It is understood that fish can be produced through increased utilization of presently underutilized resources.

— It is AID's policy to focus on the needs of the rural poor.

— AID projects are designed to improve nutrition of the poor.

— AID projects are designed to provide employment for the poor thereby increasing their purchasing power.

— There is a general recognition within AID that many of the agency's earlier efforts to encourage large-scale industry did not have the desired impact on the poor target groups.

There are, of course, many other policies that influence project design and implementation, but for the purposes of this paper particular attention will be paid to those stated above.

The comment is often made that these are good guidelines, but that in practice it is very difficult to insure that benefits actually reach the poor. This paper was written in an attempt to describe how AID strives to insure that benefits from aquacultural development do reach the target groups, and to stimulate discussion on this topic. The experience and practices of other agencies are solicited and a frank discussion of successes and failures is invited. It is hoped that development agencies can find means of increasing their effectiveness in development projects through such discusion.

AID Approach

The approach to aquaculture utilized by AID to encourage involvement of the poor involves utilization of underutilized local resources whether they be labour, water, poor land or organic wastes. If the resource most readily available is labour, a project is designed to utilize the labour resources heavily. Generally the underutilized resources have a low cost, so their use is consistent with use of most economical inputs. Use of low cost inputs certainly does not insure profitable production and mayor may not be related to the efficiency of production.

Smallscale units are encouraged in most instances because land holdings are typically small, because poor farmers have little to invest, and because management of small ponds is relatively easier than management of large ponds. Some risks are involved in beginning a fish farming activity and even if the farmer risks no more than his labour and some manure, these inputs have alternative uses and some real value. A poor farmer usually cannot afford to gamble on innovative production practices of any type. Even after he is convinced the fish farming method he will use is a good risk, he will want to begin on a smallscale.

If no previous experience with aquaculture exists in the community of fishermen or farmers involved, a very simple approach to aquaculture is encouraged initially. A slow increase in the level of complexity of fish production is programmed following general acceptance of the simple methods and general understanding of basic concepts by the fish farmers. Even if farmers have experience with aquaculture, new technology is introduced slowly as the farmers gain management experience. In this sense, it is important that fish farming be viewed as animal husbandry rather than as agronomy or as an industrial process. The value of experience in working with animals being raised is well understood with most forms of animal husbandry but is frequently not recognized for aquaculture.

A part of the AID approach closely related to the previous point is the selection for culture of ecologically efficient fish or shellfish which feed low on the food chain. Animals feeding on detritus, phytoplankton or zooplankton can usually be produced with smaller inputs in terms of feed costs and water quality management than those which feed naturally on fish or those which require high protein foods. The production methods are also often relatively simple for these animals. Usually the fish feeding low on the food chain are less expensive fish making them more readily available to poor consumers. The use of prepared fish feeds, especially those containing animal protein, is encouraged only in some instances and only after careful examination of the local feedstuff supplies and local economics of feed usage by fish compared with other potential uses. Energy uses in aquaculture are minimized as a matter of policy and this policy meshes nicely with the use of ecologically efficient species or groups of species.

Strong government support for aquacultural development is encouraged in AID projects. This support includes an extension role usually coupled with a hatchery to supply fingerlings, training for government fisheries people and technical assistance in the early stages of the project. These forms of government subsidy seem to be essential to maintain interest, to provide fish for stocking and to solve problems arising periodically on the fish farms. A long-term commitment by the government to provide these inputs is essential to industry development in most cases.

Private enterprise is encouraged in all phases of aquaculture including hatcheries and marketing. Government subsidies, hatchery operations, feed manufacture and extension work are designed to encourage private sector inputs and participation rather than as a sole source of these inputs. Often private industry has provided fingerlings, feeds, fertilizers and technical know-how more efficiently than government once technical methodology is in place. There are situations where land ownership patterns or the need to involve the landless poor have led to the development of community ponds rather than privately operated farms. Experience with community ponds is limited and the social aspects of assigning work responsibilities as well as of distributing harvests or income can become critical issues. AID is, nevertheless, encouraging community ponds as a useful and viable approach under certain circumstances.

Local consumption of part of the fish by producers is encouraged. Production of low-priced fish or production of several species in polyculture may lead to local consumption of part of the harvest. This tends to be true particularly if feed and fertilizer costs are low. If, on the other hand, costs are high, the farmer may be forced to sell to recover this costs. Combined livestock-fish production has been successful in providing fish for local consumption when the livestock are used as the cash crop and animal manures are the only fertilizer—feed used for the fish. In Panama a practice of harvesting only small tilapia on a weekly basis has encouraged local consumption by people in need of animal protein. The most successful means of accomplishing this goal is simply to produce efficient species yielding large quantities per unit area rather than less efficient, higher priced species.

New Opportunities

Although there are many different sets of goals and objectives among development agencies and government fisheries departments, and some of these objectives will lead to very different approaches than the one outlined here, it is assumed for purposes of this discussion that providing food and income for the rural poor is of general interest and that many fisheries development agencies include this as at least one of their objectives. A large set of possibilities exist for increasing benefits from aquaculture to the rural poor. Some of these have been used to a limited extent, but all are deserving of further exploration and experimentation. In the following paragraphs some of these possibilities are examined briefly.

Ownership policies for property rights to coastal land and water offer a unique opportunity for management to benefit the poor. In many countries coastal wetlands and waters are in the public domain and numerous alternatives exist for leasing, sale, or grants of small parcels to small farmers or fishermen for aquaculture. Allocation of submerged lands for shellfish farming or for cage culture of fish offers similar potential. Even the landless poor could share in the development of aquaculture if government policies are designed to further this end. However, this possibility may soon be lost in some countries. As the value of coastal lands is realized, control over these areas is being established by wealthy businessmen or farmers in a number of countries. After ownership has once passed from public to private hands only major land reform initiatives will make the lands available to the rural poor. Prompt action is required by government fisheries departments if the door is to be left open for use of coastal lands to directly benefit the rural poor.

A second possibility for involvement of the landless poor in aquaculture that deserves further consideration is the use of government or public lands or waters for community projects. The principal difficulties with community projects are social problems, and experience with aquaculture has ranged from very good to very bad. There is considerable need for experimentation with different approaches to the social problems, new structures for cooperatives or community projects, and the use of special incentives among the participants to insure equitable allocation of responsibilities and benefits from such projects. Work of social scientists in areas other than aquaculture may be applicable here, but it appears that necessary research has only begun. An exchange of ideas between countries on this topic would be most useful as a means of expanding practices used successfully.

The continually rising costs of energy have a direct impact on the poor aquaculturist limiting or prohibiting practices such as pumping requiring use of petroleum fuels. Uses of alternative energy inputs in aquaculture has been a topic of considerable discussion but little action. The opportunities for application of wind driven or water powered pumps or aerators are good. If these units can be designed to permit construction from locally available materials the potential for beneficial applications by low-income producers is excellent. In these cases it will be possible to convert wind and water power directly to fish by increasing production.

An aspect of aquaculture well suited to the poor farmer or labourer is that it can be carried out with part-time labour. Either pond culture or culture of shellfish or fish in natural waters can be accomplished with inputs of a few hours a week and the timing of most labour inputs is not critical. This makes small-scale aquaculture an attractive part-time activity to supplement sources of food and income from other forms of employment. A part-time approach to aquaculture has not yet been promoted on a wide basis, but should be because of its applications to improving the welfare of the poor.

New government subsidies to encourage aquacultural production should be considered. With agriculture it is widely recognized that government assistance in the form of subsidies is broadly beneficial to the economy. These subsidies take the form of farm-to-market roads, rural electrification, irrigation systems, marketing services, loan programmes, research, extension and training programmes, product quality control and disease control assistance among others. Similar subsidies for aquaculture are needed, particularly since it is a new endeavour in many locations and special assistance is therefore required. Government support for the aquaculture industry is typically weak even though the potential benefits of strong assistance programmes to the rural poor are clear.

The usual subsidies in the form of hatcheries, extension programmes and research are important and should be continued. One special form of government assistance, loans to farmers for initial capital costs of aquaculture operations, is particularly important for low-income aquaculturists. The poor usually have neither the money to invest in aquaculture nor property to use as collateral for a loan. If low-income people are to be included in the aquacultural development process new special sources of money are needed. Agricultural co-ops sometimes fill this need for agriculture but few channels are open for aquacultural loans, particularly for unsecured loans of the type needed to involve low-income people in aquaculture.

This is not an exhaustive list of actions governments and development agencies can take to insure that benefits from aquaculture do accrue to the poor; however, it is a set of subject areas where action is needed now. It is hoped the suggestions made will lead to in-depth exploration of these and other ideas and an open discussion of the experience of interested countries in their efforts to involve the poor in aquaculture.

DISCUSSION

Many other alternative approaches to aquacultural development are being followed and each has value in achieving the specific development goals of a particular country. One distinctively different approach from the one outlined in this paper is the large-scale commercial development of coastal aquaculture of high-priced species such as shrimp. Several aspect, of this type of project make it attractive to developing countries. Private capital is usually available for initial investments, economies of scale are possible with large operations which cannot be achieved with small-scale production and foreign sale of high-priced fishery products produced offers a source of foreign exchange badly needed by many countries. Each country must develop its own priorities for aquacultural development and the benefits from various approaches should be carefully weighed.

In evaluating the impact of a given approach on low-income people careful attention should be given to the following items :

— numbers of people employed

— requirements for feeds and fertilizers, their sources and alternative uses

— the efficiency of the operation in terms of larger or smaller scale operations

— the income of people employed, both cash and in kind

— production per unit area and possible alternative uses of land and water

— the overall profitability of the operation and distribution of income

— price of the product and its availability to low-income consumers.

Although many aquaculture projects designed to improve the status of low-income groups are underway and cannot yet be evaluated, the performance record of these projects is extremely important. Large amounts of data on costs and benefits of such projects should soon be available and publication of these data in an honest fashion will be of great value in designing future projects of this type. Forthright discussions of how projects have succeeded and failed can be a valuable spin-off of considerable importance to development agencies. Funding of critical evaluations is one additional means of contributing to the success of aquacultural development and to the welfare of the low-income consumer.

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NON-TECHNICAL CONSTRAINTS ON THE DEVELOPMENT OF AQUACULTURE IN NEW ZEALAND

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ABSTRACT

Among New Zealand's indigenous and exotic aquatic biota are a number of species which appear to have considerable culture potential. Physical characteristics are also favourable and include a 6,500 km coastline indented with ample embayments ; plenty of streams and rivers endowed with good water quality ; a comfortable population density of 11.5 inhabitants per square kilometre ; and a propitious sub-tropical to temperate climate.

Given these favourable biological and physical circumstances, it is surprising that aquaculture development in New Zealand is so dilatory. The reasons for this state of affairs are many. Aquaculture is a late arrival in New Zealand where there exist a number of conflicting demands on water resources ; where research and development priorities reflect the dependence on agricultural and forestry production ; where there is a dichotomy between land use and water use and planning for one is often independent of the other ; where certain forms of aquaculture common in other countries are banned ; where the aquaculture developer must compete for development finance and get caught in the circular argument that because the contribution of aquaculture to the economy is insignificant at present, the nation's allotment to the industry must be minimal—this ensures that aquaculture remains insignificant !

However, in spite of this bleak picture, there may be room for some cautious optimism. Circumstances are changing. New Zealand is experiencing difficulties in marketing its agricultural products. In a move towards diversification, the potential of aquaculture cannot be ignored. There are signs that, given time, New Zealand will make use of its invaluable water resources.

INTRODUCTION

THE NEW ZEALAND Government has pledged its support for the development of aquaculture (National Party, 1978) and the Minister of Fisheries, in his address to the National Aquaculture Conference (MacIntyre, in press) in Wellington in September 1979, declared that the time has come when aquaculture in New Zealand should not be considered just as a concept. These reassurances are long overdue since the productive potential of water is probably the most underutilised single natural resource in New Zealand.

I wish to thank the Commissioner for the Environment for granting me permission to conduct this study and Ms. Lynette Young for typing the manuscript.

RESOURCES

Physical environment

New Zealand comprises three islands (Fig. 1) and lies between latitude 34°S and 48°S. The lengthy coastline (about 6,500 km) is greatly indented in places. Good examples of this are, the Bay of Islands, the Marlborough

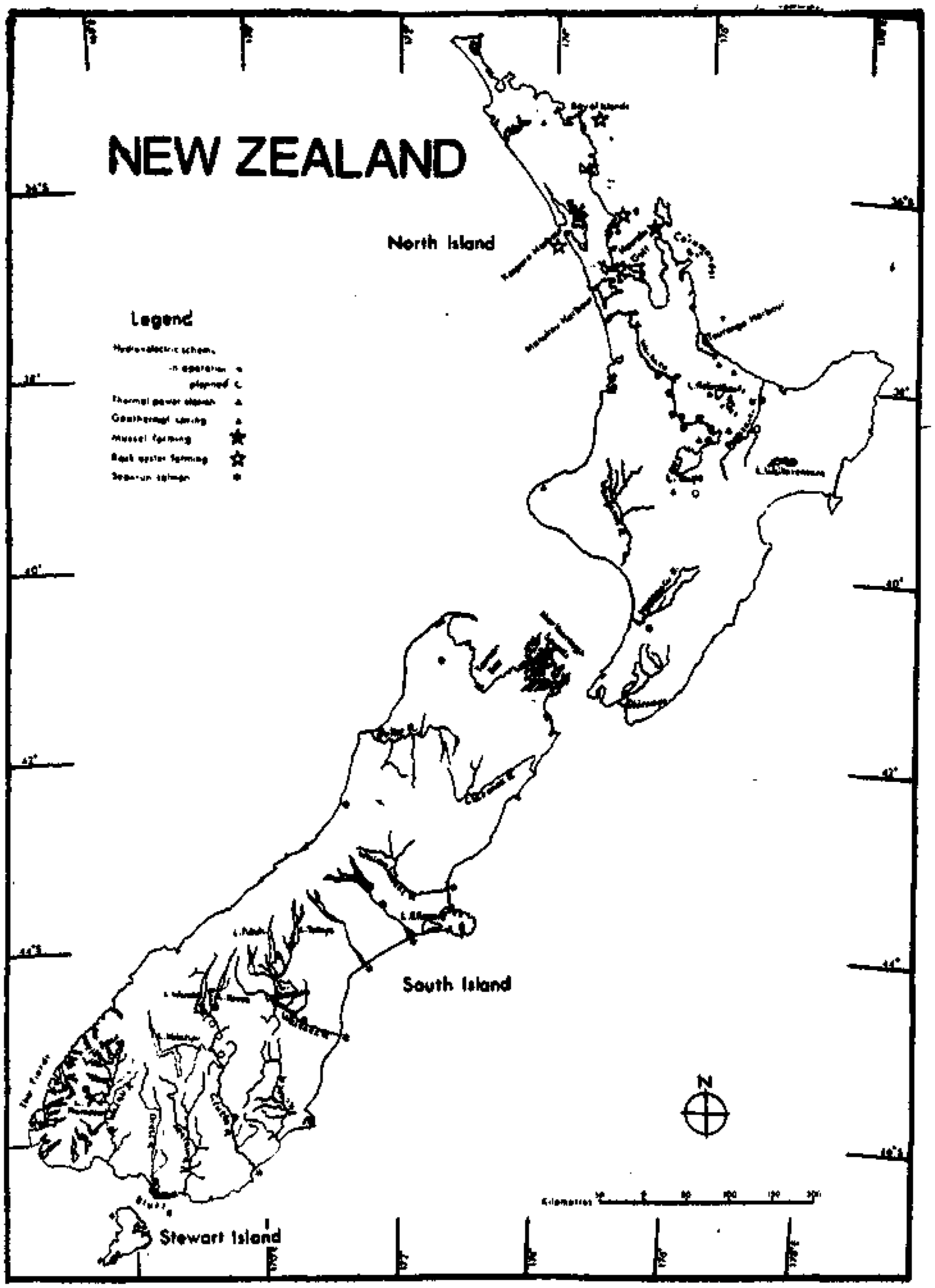
NEW ZEALAND
North Island
Legend
South Island
N
Stewart Island

Fig. 1

Sounds and the Fjords shown in Figure 1. Mangrove swamps abound north of latitude 38°S in the North Island while extensive mud-flats are found in the Kaipara and Manukau Harbours, Tasman Bay and the Bluff area.

The New Zealand climate is influenced by the westerly wind flow. There is a general tendency for winds to increase in strength from the north to the south of the country. An average of about twenty tornadoes and waterspouts are reported in New Zealand each year but most of these are small and rarely do they do any damage. The Cook Strait region between the two main islands and Foveaux Strait between the South Island and Stewart Island are especially windy.

The sunniest areas of New Zealand are to be found in the northern part of the South Island where sunshine exceeds 2,400 hours per year. A large portion of the remainder of the country receives about 2000 hours. Mean air temperatures at sea level decrease from 15°C in the far north to 12°C about Cook Strait and 9°C in the south of the South Island. Average rainfall for the whole country is more than 2,000 millimetres and for most areas lies around 1,200 millimetres. Sea surface temperatures range from a mean of 18°C in the north, to 9°C in the south. As can be expected, areas close inshore are warmer in summer and colder in winter than offshore waters.

Water quality in most inland and coastal waters is comparatively good. New Zealand is removed from the main international shipping routes and oil slicks, tar balls and similar pollutants are rare. Most pollutants are of terrestrial origin and usually from agricultural sources. Large sections of coastline and inland waters away from urban centres are in pristine condition and low population pressures (density between 11 and 11.5 per square kilometre) indicate that this high quality is likely to be maintained.

Geothermally heated springs are plentiful in some areas of New Zealand as indicated in Figure 1. The quality of the water in these springs is variable. Some springs can be used directly for aquaculture, but others may only be used as a source of heat through heat exchangers. In either case, geothermal heat can alleviate energy costs, often one of the major contributors to the operating costs of an aquaculture system.

Man-made resources

New Zealand depends, to a large extent, on hydro-electric schemes for its electrical energy. The lakes, canals and raceways which form part of these schemes could probably be used to culture aquatic organisms. There are no nuclear power stations in New Zealand and the small number of thermal stations are fuelled by coal, natural gas or oil. Depending on the station's location, freshwater or seawater is used for cooling and the effluent is usually about 10°C above ambient temperature. The Ministry of Energy has established a pilot project to investigate the feasibility of cultivating shellfish in condenser cooling water, thus utilising the waste heat (Tortell, 1978).

Any discussion of waste utilisation of New Zealand would be incomplete without reference to the vast quantity of wastes from agricultural production and processing. This resource, yet to be exploited, is the by-product of an industry which in any one year can produce and process up to 25 million lambs, 6 million sheep, one million calves, 2 million other cattle and nearly one million pigs ; three-quarters of a million tonnes of butter, cheese and related dairy products ; and some half a million tonnes of wool (Department of Statistics, 1978). An aquaculture industry based on these ' wastes ' would benefit from reduced feed and fertilizer costs making the products extremely competitive.

Furthermore, a wastewater aquaculture system is also an efficient agent of water renovation, capable of removing wastes from water thus making it available for other uses (Tortell, in press a). The New Zealand Commission for the Environment has recognized the potential of waste nutrient utilisation and has compiled a directory and bibliography on the subject (Tortell, in press b).

Biological resources

Of the 23 species listed in Table 1 only three are being cultivated on a commercial scale, seven or eight are under investigation and the majority are yet to be considered.

Rock oysters were the first marine product to be cultivated in New Zealand. Oyster farms were first established in northern New Zealand in 1967 by the then Marine Department. After an initial rush for leases and licences and a number of abandoned farms, the industry has settled down and production is steadily increasing. The uninvited appearance of the Pacific oyster at first caused some problems to the industry but resourceful farmers now manage the two species successfully side by side. The industry has been backed by research carried out by government agencies (Curtin, 1971, 1974 ; Dinamani, 1973, 1974, 1975) and is at present in a buoyant state. However, production (1,000 tonnes a year) is limited by the rack method employed and attempts at suspension culture are certain to meet with opposition.

Mussel farming only became established as an industry in New Zealand within the last five years or so. Research and assistance to the industry have come from universities (Flaws, 1975 ; Tortell, 1976), government agencies (Hickman, 1975, 1979 a, 1979 b) and the Fishing Industry Board (Meredith-Young and Jenkins, 1978 ; Jenkins, 1979). The technology is certainly available in New Zealand. In fact it has been used to assist the establishment of mussel farming in other countries (Tortell *et al.*, 1978). Production estimates are high (Tortell, 1977) and considering its potential use as a medicinal (Croft, 1979), the New Zealand mussel should not have any future marketing problems. However, the development of mussel farming in New Zealand has been rather unplanned and the industry is still struggling.

Combined research by the Ministry of Agriculture and Fisheries and private enterprise on ocean ranching of salmon is well-advanced and its feasibility established (Campbell, in press). However, salmon culture in New Zealand is not poised for immediate success and the constraints are neither technical nor biological. Investigations on the culture potential of scallops, paua (abalone) and other shellfish, swimming crabs and marine algae are either under way or planned and it is only a matter of time before the technical and biological know-how is available for the prospective aqua-farmer.

TABLE 1. *Some of the aquatic organisms that are, or could be cultured in New Zealand*

Group	Taxonomic Name	Common Name	Origin	Culture Status
Oysters	*Crassostrea glomerata*	rock oyster	native	cultured
	Crassostrea gigas	Pacific oyster	introduced	cultured
	Ostrea lutaria	Foveaux Strait oyster	native	managed, not cultured
Mussels	*Perna canaliculus*	green-lipped mussel	native	cultured
	Mytilus edulis aoteanus	blue mussel	native	reluctantly cultured

Group	Taxonomic Name	Common Name	Origin	Culture Status
Crabs	*Ovalipes catharus*	swimming crab	native	research on going
	Cancer novaezelandiae	cancer crab	native	fairly good potential
	Plagusia chabrus	red rock crab	native	fair potential
	Scylla serrata	mangrove crab	occasional visitor	good potential
Scallops	*Pecten novaezelandiae*	scallop	native	research on going
Abalone	*Haliotis iris*	paua	native	research on going
Clams and Cockles	*Amphidesma ventricosum*	toheroa	native	fairly good potential
	Amphidesma subtriangulatum	tuatua	native	good potential
	Amphidesma australe	pipi	native	good potential
	Dosinia anus	coarse dosinia	native	fairly good potential
	Austrovenus stutchburyi	cockle	native	good potential
Lobsters	*Jasus edwardsii*	common crayfish rock lobster	native	fair potential
	Jasus verrauxi	smoothtail or packhorse crayfish	native	fair potential
Fish (marine)	*Chrysophrys auratus*	snapper	native	fairly good potential
	Regificola grandis	yellowtail	native	good potential
	Rhombosolea plebeia	sand flounder	native	good potential
	Rhombosolea leporina	yellow-belly flounder	native	good potential
	Mugil broussonetri	grey mullet	native	good potential
Carp	*Ctenopharyngodon idella*	grass carp	introduced	good potential
	Hypophthalmichthys mollitrix	silver carp	introduced	good potential
Eels	*Anguilla dieffenbachi*	long-finned eel	native	research on going
	Anguilla australis	short-finned eel	native	research on going
Salmonids	*Salmo trutta*	brown trout	introduced	good potential
	Salmo gairdneri	rainbow trout	introduced	very good potential
	Oncorhynchus tshawytscha	quinnat salmon	introduced	promising attempts
Freshwater crayfish	*Paranephrops planifrons*	koura	native	research on going
	Paranephrops zelandicus	koura	native	research on going
Seaweeds	*Gracilaria secundata*	gracilaria	native	research on going
	Macrocystis spp.	bladder kelp	native	fair potential
	Pterocladia lucida	comb weed	native	good potential
	Codium fragile	branching velvet weed	native	fairly good potential
	Caulerpa brownii	sea rimu	native	fairly good potential

Constraints

The technical know-how for the cultivation of native or introduced aquatic organisms is either already available in New Zealand or obtainable through further research and experience.

But, no amount of research will make trout farming legal in New Zealand. No research can convince a maritime park board to accept a marine farm in waters adjacent to a scenic reserve on land, although the same board has no objections to sheep farms sharing the boundary with the reserve. No research can streamline the processing of an application for a licence to farm mussels—a process which can take over two years and involve eleven government agencies, four local authorities and a host of sporting and recreational bodies (Jarman in press).

Conflicts in water use

The internal waters and territorial sea of New Zealand are vested in the Crown and have traditionally been considered common property with the exception of some Maori-owned waters of historical significance. The right of unrestricted access to and from the foreshore the freedom to navigate on any water, the right to anchor and seek shelter and the right (within certain conservation limits) to fish or gather shellfish for personal use are enjoyed by all New Zealanders. These rights and freedoms permit all uses of water that do not have an obvious impact on its quantity or quality. Among these uses are : swimming, sunbathing, recreational fishing, rowing, sailing, powerboating, water-skiing, scuba and skin diving. Any restriction of these rights is bound to be strongly resisted.

This attitude is not realistic since it is inevitable that the concept of land use planning must be applied to marine resources in the not too distant future. In fact, areas of sea and seabed are already being reserved for specific uses, e.g. ports and harbours for commerce and navigation, restricted areas for national defence purposes, marinas for the mooring and servicing of pleasure craft, marine reserves for scientific study and sewage out fall areas for the disposal of wastes.

Therefore, while access to and enjoyment of water resources is every New Zealander's inalienable right, this right has already, albeit unwittingly been restricted. Aquaculture is a further threat to these freedoms and as such it is opposed often on principle.

While certain uses of water are mutually exclusive, others can be accommodated together. Identification of potential incompatibility and careful planning can resolve most conflicts.

Gopalakrishnan (1976) identified 24 coastal zone uses and expressed their relationship in terms of the following five categories :

(*a*) *Essential :* Uses or activities essential to orderly coastal development—these uses have priority.

(*b*) *Supplemental :* These uses tend to supplement one another economically without conflict.

(*c*) *Mutually exclusive :* Only one such use can be accommodated in a given area, to the exclusion of all others.

(*d*) *Competitive :* Uses that can go on simultaneously but between which there will always be contention for priority, precedence, etc.

(*e*) *Indeterminate :* No discernible relationship—at least none of any consequence.

The compatibility matrix in Figure 2 is based on Gopalakrishnan (1976). The original 24 coastal zone uses are augmented by different forms of aquaculture activities as well as land uses that may have an impact on water quality.

According to Figure 2, administration requirements, wharves and similar structures, access and rights of way, port facilities, navigational requirements and oil and gas prospecting and production normally have priority over most other activities including marine farming. National parks and other reserves on land also as swimming, water-skiing, surfing, sunbathing and sport fishing. On the other hand, marine farming and some other water uses are mutually exclusive. These include, sand and shingle mining, scientific marine reserves and waste

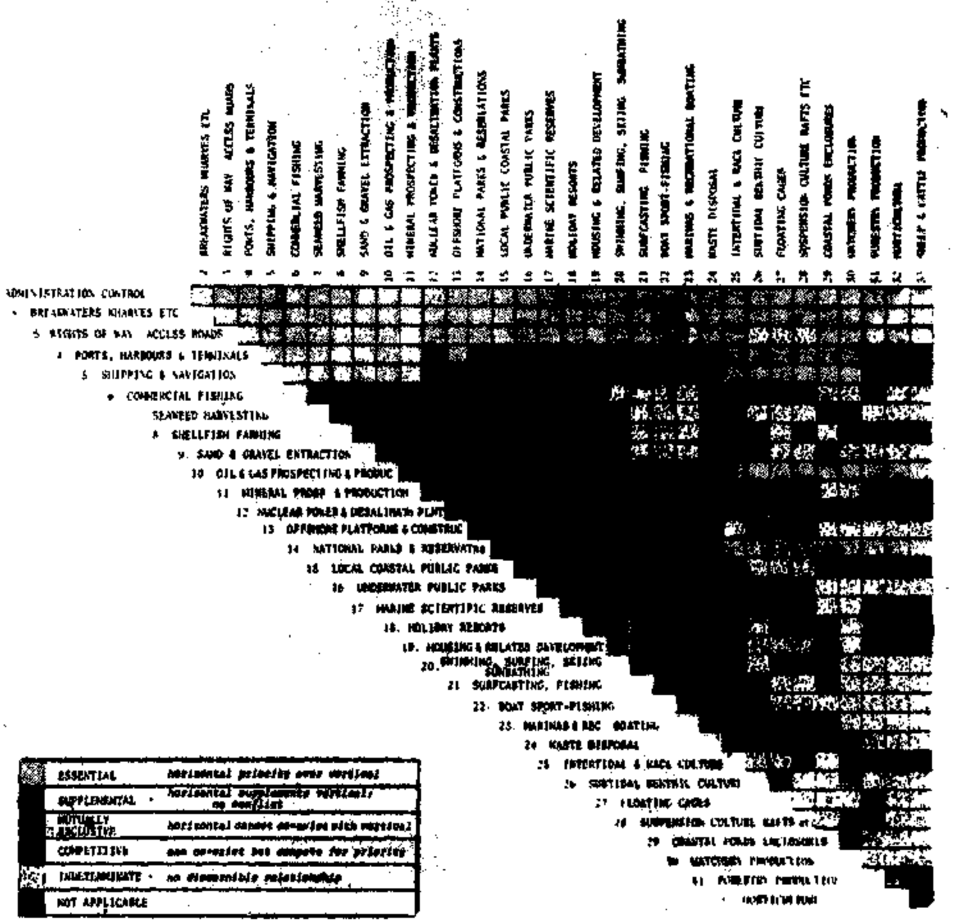

Fig. 2. Compatibility matrix for mulitiple uses of coastal water resources (After Gopalakrishnan, 1976).

tend to take priority over most forms of marine farming. Commercial fishing often conflicts with aquaculture, however, while competing for priority the two activities can co-exist, and may even share some facilities. A similar relationship exists between marine farming and seaweed harvesting, some types of holiday resort, recreational boating and activities such disposal. Forestry tends to compete with floating cages and other types of suspension culture but the two activities can co-exist.

Land uses with an impact on water

Agriculture is the mainstay of the New Zealand economy. Production forestry and, more recently, horticulture, also make a significant contribution to the country's balance of trade. Intensive primary production as practiced in New Zealand depends on a continuous and high input of fertilizers and pesticides and other chemicals to control the many problems that plague monocultures. A large proportion of these artificial chemicals, especially when applied by aerial spreading, sooner or later find their way into water courses. Waters that are so affected may not be suitable for aquaculture.

Sheep and cattle farms, even without the application of artificial fertilizers, are notorious non-point sources of enrichment. Within certain limits this may enhance aquaculture production. However, enriched waters tend to also encourage the growth of fouling organisms and in the long run may create more problems for the aquafarmer. Coliform counts are the traditional indicators of possible contamination. Since it may not always be possible to distinguish between those coliforms of human origin, those from farm animals and those from vegetation, aquaculture in the vicinity of farms may not be permitted because of the high (but possibly inconsequential) coliform counts.

As established forest normally leads to an enhanced water quality within its catchment. But, when the area is first cleared for planting and later, when the trees are harvested, the ground is extremely vulnerable to erosion. Vast amounts of top soil and silt can be washed into rivers and on to estuaries with the resultant high turbidity and eventual siltation that can adversely affect some forms of aquaculture. A further potential conflict between forestry and aquaculture is to be found in areas where road access is poor and the timber must be taken out by rafting or by barge. Marine farms other than on the seabed will create a barrier and impede the export of logs from the area.

Horticulture does not normally provide the ground cover associated with an established forest or pasture and the loose, rich soil can be carried away by rain as well as wind. Apart from this impact on water quality and the leaching of pesticides which are used more intensively in horticulture, there is also an impact on water quantity. Fruit, vegetables, flowers and other crops often require irrigation, normally at a time when rivers are naturally low. The abstraction of water for irrigation can have a drastic impact on the river biota and seriously impair downstream uses. Decreased river flow volumes may also influence the physical configuration of the estuary.

Four out of five New Zealanders live in urban areas and the great majority of these are on the coast. Those that are not, are invariably situated on a river, never too far from the coast. Residential development in urban areas, as well as in holiday resorts or weekend accommodation may conflict with aquaculture. The most obvious clashes are access, navigation, aesthetics and interference through curiosity but these are not insurmountable and can often be resolved by careful planning. More serious are the possible restrictions placed on the developer or home owner because of the presence of aquafarms. For example some forms of waste disposal may not be permitted because of their potential impact on marine farms.

There are close to 50 sewage outfalls into the coastal zone around New Zealand and twice as many into river systems. As can be seen from Table 2, most discharges are treated to a greater or lesser degree, but a few consist of raw, untreated effluent. The New Zealand Department of Health is not against the disposal of effluent into rivers and coastal waters since it is of the opinion that such discharges do not have a significant impact. However, in the interest of public health, the presence of a sewage outfall precludes any swimming, fishing and marine farming.

Residential development has another impact on water quality and aquatic organisms, Neilsen and Nathan (1975) found a high concentration of lead in green-lipped mussels, *Perna canaliculus* from areas adjacent to urban development. They could only attribute this to the input of lead from motor vehicle exhaust and from anti-corrosive roof paints, carried into the coastal zone through stormwater drains.

TABLE 2. *Treatment and disposal of sewage in New Zealand*

Treatment	River system	Lake	Estuary Harbour, Ocean outfall	Land irrigation
Raw effluent ..	6	0	7	0
Screening comminution holding Tanks ..	7	1	14	0
Imhoff, primary treatment ..	19	4	11	0
Oxidation ponds activated sludge trickling filter ..	67	2	15	15

Legislation and administration

Marine farming commenced officially in New Zealand in 1964 with the passing of the Rock Oyster Farming Act. The first oyster lease was granted in 1967 and in 1968 the Marine Farming Act was passed to allow the farming of marine species other than oysters. However, this act proved unworkable (Anon, 1974) and in 1971 a new Marine Farming Act was passed.

The Marine Farming Act 1971 is an act to:

> '...consolidate and amend the law relating to the establishment and development in New Zealand waters of an industry for the farming of seafish, shellfish, oysters, and marine vegetation, the leasing and licensing of marine farms, and the marketing of fish, shellfish and oysters reared and marine vegetation cultivated in marine farms.'

It repealed earlier statutes and after some amendments became the operative instrument for the granting of licences to prospective marine farmers. In this respect, New Zealand is ahead of many other countries in having passed legislation enabling marine farmers to be licenced and protected by law. Figure 3 shows the process that an aspiring applicant must go through and the agreements that he must secure. Currie (1974) estimated that an application can be processed within 22 months—in reality the process normally takes a minimum of 30 months. The extra time required before a licence can be granted is normally due to the investigation and assessment phase which is often carried out separately for each application.

Since natural waters are basically public property in New Zealand, and since the granting of a marine farming licence is in effect transferring ownership to a private individual, it seems only just that each application is carefully scrutinized and evaluated. However, many aspects of the investigation and assessment need not wait until the Ministry received a firm application. Indeed, the Ministry is empowered by the Marine Farming Act to survey the New Zealand coastal environment and determine which areas are suitable for marine farming.

The Ministry has undertaken two such surveys, both within the last year. The climate in which they were undertaken and the manner

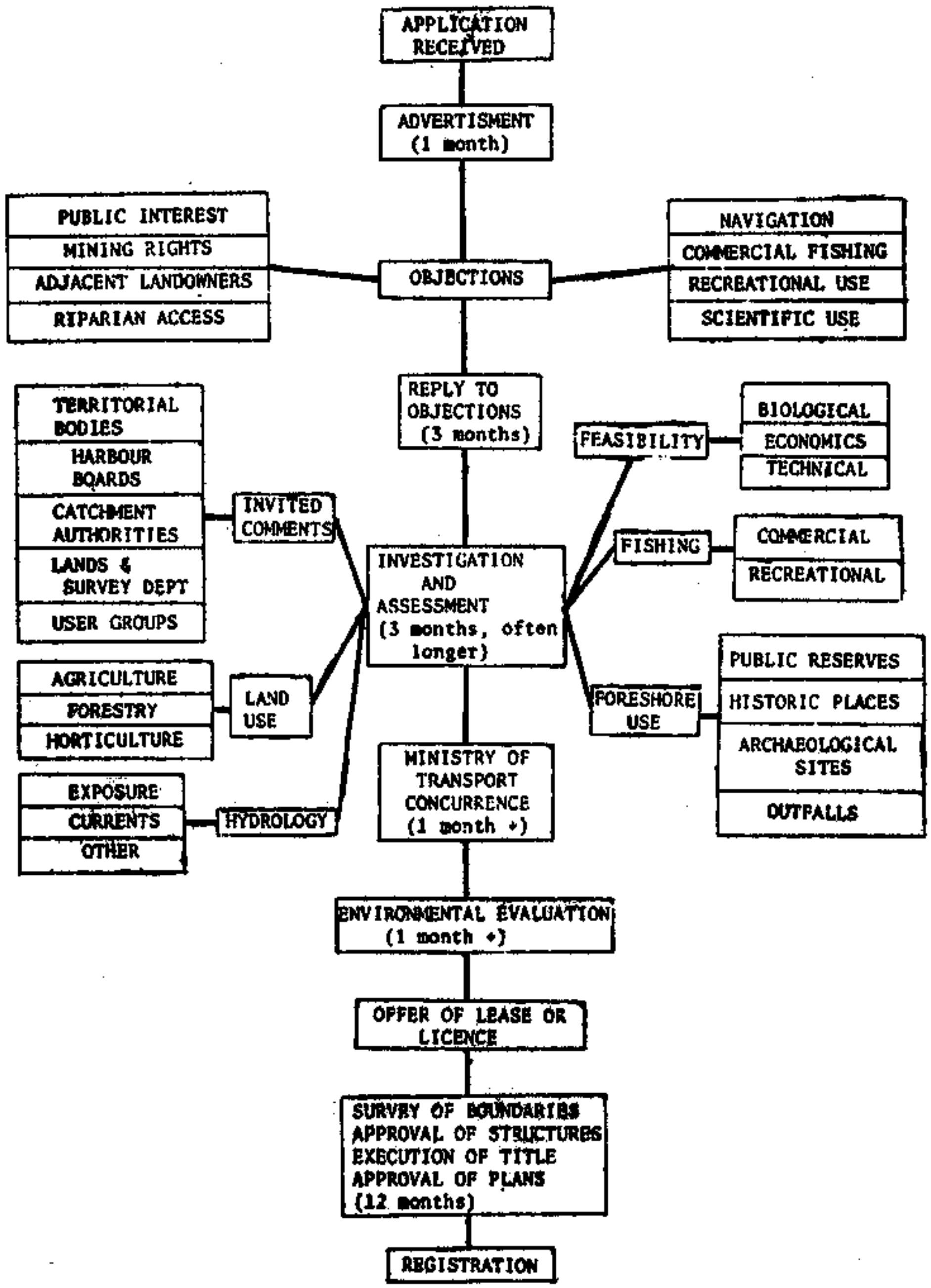

Fig. 3. Flow diagram of the processing of an application for a marine farming or licence (after Currie, 1974)

in which they were made public, generated a great deal of antagonism. It seems that aquaculture in New Zealand is automatically and irrationally opposed on principle. The granting of a marine farming licence is seen by many as a capricious act by the Ministry to donate public areas for selfish exploitation by an individual. This unfortunate state of affairs is caused by the absence of an aquaculture development plan, the lack of public participation to date in the process of planning for marine farming, the denial of any right of appeal after the Minister of Fisheries has decided whether to uphold or reject an objection, and a general lack of appreciation of the food value and export potential of aquaculture products.

The farming of salmonids, eels and freshwater crustaceans is not covered by the Marine Farming Act of 1971 but falls under the Freshwater Fish Farming Regulations of 1973 promulgated pursuant to the Fisheries Act of 1908. These regulations contain some excellent guidelines for the operation of fish farms and fish processing plants. In particular, the provisions to guard against disease and its spread appear admirable. However, in spite of these regulations and the provisions they make, commercial freshwater fish farming in New Zealand is virtually non-existent.

Rainbow and brown trout have been reared in New Zealand since the second half of last century. However, all trout hatched and reared in New Zealand are liberated to stock the renowned angling rivers. Applications to farm trout commercially have not been granted and such is the strength of the anglers' lobby that it is unlikely that any will be granted in the near future.

New Zealand rivers also boast an introduced quinnat salmon fishery (Fig. 1), which up to a few years ago was the only sea-run salmon in the Southern hemisphere. While attempts to farm salmon have not been completely stifled as with trout, the prospective salmon farmer must battle every step of the way. It is surprising that the small handful of salmon farming attempts have survived this long in the face of crass opposition as expressed by the President of the NZ Salmon Anglers Association who said in his October 1979 report:

> 'The concept of ocean ranching was to further increase the run of salmon in the river, the salmon angler was to have first access to the returning adult salmon and the anglers' interest was always to remain paramount when considering the formation of any salmon farm.' (Anon, 1979 a)

Freshwater and marine aquaculture are regulated by different statutes and this has led to inconsistencies. Provisions for water quality are even more complex since they appear in two separate statutes. The Water and Soil Conservation Act of 1967 grants regional water boards the responsibility to regulate water use and protect water quality over all New Zealand waters up to the limits of the territorial sea (12 nautical miles). The Marine Pollution Act 1974 regulates against polluting discharges and dumping in the territorial sea of New Zealand and in all navigable internal waters (*i.e.* most lakes and rivers).

Figure 4 shows that there are at least 31 acts which operate on the coastal zone in New Zealand. A number of these extend from the hinterland out to the limit of the territorial sea, and four acts apply to the New Zealand Exclusive Economic Zone (200 nautical miles). All but one of these acts are specific in their intent and each promotes, regulates, protects or manages a particular resource for a particular purpose. The one exception is the Town and Country Planning Act of 1977, which is intended to plan for the wise use of terrestrial and marine resources in general. The coastal zone is served by the maritime planning provisions of the act but early hopes that this act would lead to coordinated total planning

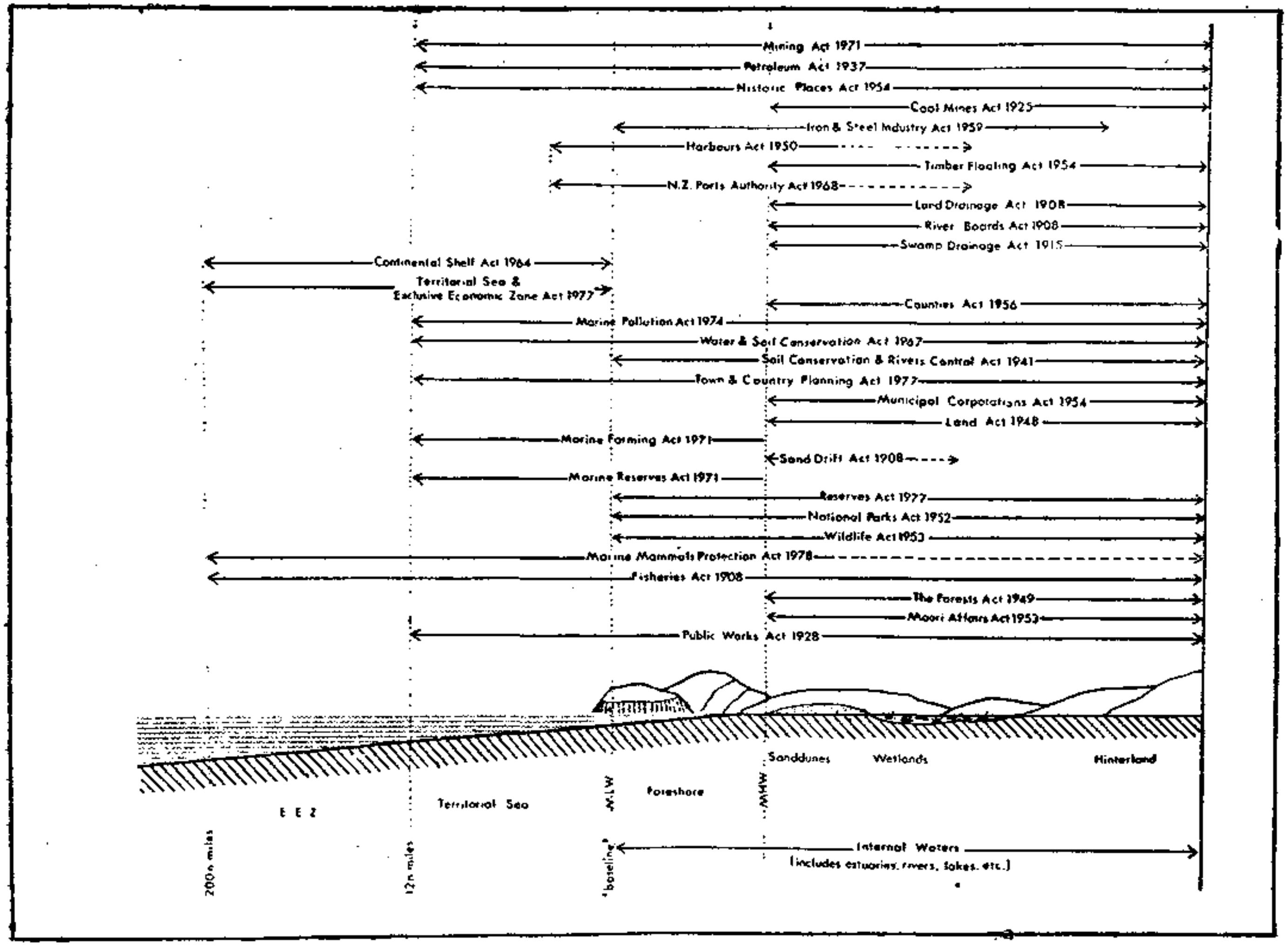

Fig. 4. Legislative administration of the coastal environment (After Knox, 1977).

extending over catchment, river and coastal zone have not yet materialized. The dichotomy between land and water use planning still exists, and serves to accentuate the problems that must be faced by the prospective aquafarmer.

Investment and finance

Pillay (1977) points out that the development of aquaculture calls for appreciable investments in terms of various supporting services, including research, training, extension and information, as well as appropriate incentives for attracting the necessary capital.

According to the annual report of the National Research Advisory Council (1979), New Zealand spent $ 3.8 million on fisheries research in the year ending March 1979. Of this, an estimated $ 0.5 million was spent on aquaculture-related research. During the same period, the expenditure on forestry research was $ 6.5 million and that on agriculture was $34.6 million. This is hardly surprising in view of the fact that annual agricultural export are usually worth about $ 2,000 million,exports of forest products $ 200 million, and fisheries exports a mere $ 46 million. The export value of oysters and mussels (presumed cultured) was $0.8 million.

However, as Table 3 indicates, although the total sum spent on aquaculture research is small, it is considerably higher than other research spending when considered in relation to export earnings.

Research in the fields of forestry and agriculture encompasses production techniques, biology, processing and marketing. Aquaculture research to date has been almost exclusively of a biological nature. The New Zealand Fishing Industry Board conducts research on aspects of processing and product presentation from time to time but this work is comparatively small scale.

Recent moves by Government to attract capital and to promote private investment in aquaculture are encouraging (Anon. 1979 b). The Rural Banking and Finance Corporation has available loans for up to 50% of the initial development cost of oyster and mussel farms. The interest rate on these loans is 9% and the repayment period between five and seven years. Marine farmers also qualify for income-tax concessions in the form of investment allowances for boats, plant and machinery. Certain items normally considered capital expenditure on a marine or freshwater farm and therefore not normally deductable for tax purposes, can be considered as development expenditure and deducted from taxable income.

One final incentive which aquafarmers can qualify for is a grant for new developments in the field of aquaculture. This grant, administered by the Ministry of Agriculture and

TABLE 3. *Primary production ; export returns and research spending ($ million)*

	Fisheries	Aquaculture***	Forestry	Agriculture
Returns* ..	46	0.8	200	2000
Research** ..	3.8	0.5	6.5	34.6
% research/returns ..	8.24	62.5	3.25	1.73

* Department of Statistics, 1978 ;

** National Research Advisory Council 1979 ;

*** Estimate only

Fisheries is to assist the industry make the best possible use of, or gain the best possible economic benefit from, the living aquatic resources of New Zealand. There are also export incentives available in the form of suspensory loans, new market development grants and others.

Although still lagging behind the support for agriculture with its intricate system of subsidies, and other incentives, the financial support available to aquaculture in New Zealand while limited, is by and large, encouraging.

The Future

New Zealand is facing problems in maintaining its traditional markets for agricultural products. There are moves to diversify both the markets and the products and this may be an opportune time to explore New Zealand's aquaculture potential.

New Zealand is endowed with a favourable environment and a number of aquatic organisms which appear to have culture potential. This combination augurs well for the development of aquaculture given the necessary research, planning, support and incentives.

There is a commitment to the industry on the part of Government and a significant effort is being made on biological research. There is also a considerable general interest in various forms of aquaculture. But, there is a great deal of opposition from sectors of the public which feels that its traditional rights may be threatened by this new use of the country's water resources. The case for aquaculture in the face of competing uses of water is at present so weak that in any planning exercise, marine farming is reluctantly tolerated only in those areas which are of little use for anything else—thus, areas made available for aquaculture are not always suitable.

Aquaculture should be recognized and promoted as a desirable and legitimate use of water capable of producing human food, sport fish, bait for commercial and sport fishing and other products. These products can either be used locally or exported to earn foreign exchange. Aquaculture is also capable of using organic waste and renovating wastewater thus making it available for other uses.

Since aquaculture is such a new development in New Zealand it needs the full support and special consideration of local and central government. While it may not be easy to justify a higher investment on the strength of present output, it seems reasonable to give special consideration to aquaculture in recognition of its demonstrable high potential. If confidence in this growing industry is to be maintained, government support will be needed in the form of further fiscal measures, a review of legislation and the provision of the necessary infrastructure.

Most people associated with aquaculture in New Zealand, be they researchers, administrators or farmers are largely self-taught. There is a dire need for formal training in aquaculture. Two tertiary education institutions in New Zealand specialize in training for a career in agriculture. If aquaculture is to realize its potential, tertiary education institutions should provide technical and academic training for future scientists, planners, economists, engineers and managers of aquafarms, as well as those who will process and market its products.

There is an urgent need for a National Aquaculture Development Plan which clearly sets objectives, establishes a lead agency and identifies the structure, research and promotion needed to achieve the set objectives.

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THE LUMMI INDIAN (USA) AQUACULTURE TRAINING PROGRAMME (1969-1972): MARINE BIOLOGY AND AQUACULTURE TECHNOLOGY IN A SOCIO-ECONOMICALLY DEPRESSED ENVIRONMENT

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ABSTRACT

In 1969 the Lummi Indians of Washington State (*USA*) embarked on a daring and ambitious effort to establish for their tribe a new economic foundation based on aquaculture or 'farming the sea.' Utilizing their own natural resources and with assistance from certain scientific, governmental agencies and private organizations, the Lummi Indians demonstrated the capability of successfully conducting a highly sophisticated salmon and oyster culture operation. An absolute requirement for the project was a fool of Lummi people knowledgeable and skilled in relevant aspects of finfish and shellfish culture.

Between 1969 and 1973, a series of interdisciplinary programmes were established to disseminate the knowledge and skills required for aquaculture. The programmes which were supported by the U.S. Department of Labour and the U.S. Department of Health, Education and Welfare were successful beyond the expectations proponents of the Lummi Indian Aquaculture Project.

A total immersion formate was used in the training programme in which trainees participated in classes, laboratories and field situations, eight hours per day, five days a week for a full calendar year. Trainees were exposed to basic biology, chemistry, marine ecology, fisheries and aquaculture. A major innovation in the programme was the use of peer teching and learning among the trainees. The impact of the Lummi Indian Aquaculture Training programmes on the Lummi Community has been very significant.

INTRODUCTION

IN NORTH AMERICA, there has been a recent surge of interest and activity in aquaculture. One of the most unique efforts was that of the Lummi Indian Aquaculture Project (Fig. 1). Its primary objective was to establish for the Lummi Indian Tribe (Marietta, Washington, USA) a new economic foundation based on the commercial production of salmonid fishes (*Salmo gairdneri*, *Oncorhynchus* spp.) and oysters (*Crassostrea gigas*, *C. virginica*, *Ostrea edulis*.)

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The Lummi Indian Tribe is one of the original groups inhabiting the Pacific Northwest Coast of America. Prior to the coming of the European settlers, the coastal tribes occupying the northwestern corner of Washington State laid claim to over 1.5 million acres of land and waters (Heath, 1975). The Lummi were an affluent and peaceful people whose culture revolved around the fisheries resources of the Puget Sound and adjacent waters. As has been the case with other native American groups (Brown, 1970), the coming of the white man ultimately resulted in the exploitation and demise of the Lummi Tribe and their natural resources. This trend was brought about through a long series of profit motivated and politically instigated actions by members of the immediate white communities and the federal and state governmental agencies and officials. Among the more significant events were a series of treaties (Heath, 1975) through which the Lummi were relegated to the confinement of a small reservation through what has been described by some as chicanery and coercive trickery (DeLoria, 1972).

The loss of fishing rights which were supposedly guaranteed by these treaties was brought about through the unilateral decision of the state of Washington to license all fishing of the salmon stocks upon which the Indian economy and culture depended (DeLoria, 1973). This action in effect negated the earlier agreements between the U.S. federal government and the tribes. The Lummi were no longer in control of their traditional fishing sites and were unable to compete with highly financed outfitted commercial fishing interest. It became virtually impossible for the Lummi to continue to take their usual catches necessary for the maintenance of their community.

Thus by the early 1900's the Lummi tribe was already caught in the vicious cycle of poverty, unemployment, poor health and social abuse. During the 1930's the Bureau of Indian Affairs unsuccessfully attempted to convert the Lummi fishermen to land agriculture, a form of activity which was not in accord with the Lummi tradition. In succeeding decades attendant problems of poor health, lack of educational and employment opportunities continued to plague the tribe. By 1968, it was calculated that the median family income was less than $1500, while 50% of the men and 67% of the women on the reservation were un employed (Hood, 1971). The large average family size of about 6.5 members per household (Anon., 1971) severely aggravated the low family income. The present population of the tribe numbers about 1500 individuals on the reservation and immediately adjacent areas.

During the late 1960's, the Lummi were approached by heavy industry which proposed to lease reservation lands for metal-oxide reduction plants. The tribal leaders questioned the compatibility of metal processing plants and the remaining limited salmon fishery which was restricted mainly to the reservation. The Lummi community and its leaders opted to decline the offer of industry lest the fishery resources on the reservation be jeopardized.

In 1969, it was suggested that the Lummi Tribe consider utilizing the unused acres of tidal flats, the Nooksack River and its adjacent estuaries for the purpose of commercially propagating and rearing salmonid fish and oysters. Thus the Lummi Indian Aquaculture Project was born. Within a short period of time, aquaculture became the watchword of the Lummi community which displayed tremendous support and enthusiasm for the project. The Lummi enterprise is owned and operated by the tribe and has employed many members of the Lummi community. Since its establishment in 1968, the Lummi Indian Aquaculture Project has made remarkable progress despite many major technical, financial, legal and political obstacles.

Aside from its initial impact on the Lummi community, the project is of special significance as its successes and mistakes may be of value to similar attempts being made to bring science and technology to the aid of underdeveloped or underprivileged areas in other parts of the world.

The successful operation of the Lummi aquaculture venture depended to a large extent on the efficient utilization and management of such complex facilities as a 700 + acre man-made marine rearing pond (Fig. 1), a large oyster hatchery, a modern salmon hatchery and associated research facilities. It was absolutely essential that the Lummi people directly involved in the operations have a good understanding of basic principles of shellfish

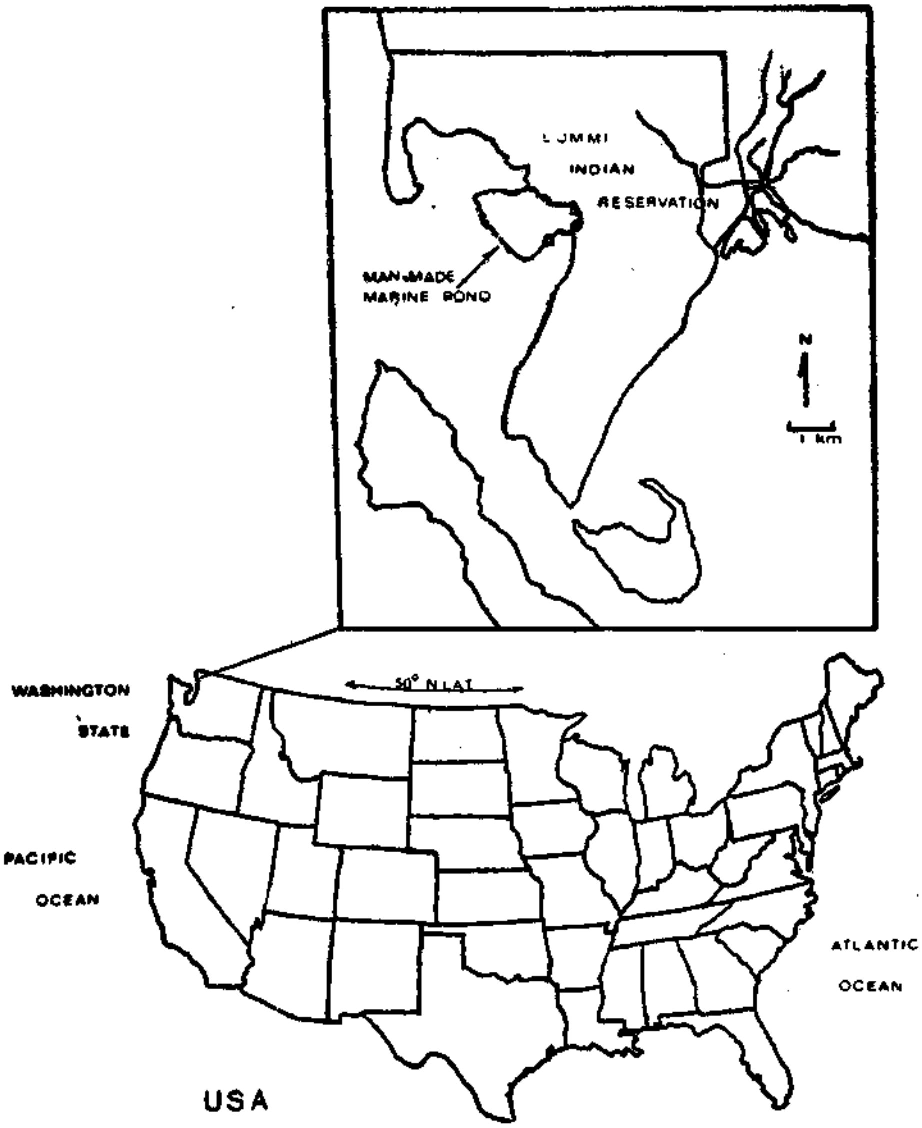

Fig. 1. A map showing the location of Washington State and the Lummi Indian Reservation. Inset shows the artificial marine pond on the Lummi Indian Reservation.

and finfish culture as well as background in certain concepts of traditional biology, ecology and fisheries.

The Lummi Indian Aquaculture Training Programmes (ATP) were established to accomplish this important and difficult task of providing appropriate training. Teaching information of this type, in this particular environment of educational depression and at the required level of sophistication was unprecedented. The actual communication of the specialized scientific and technical information was the most difficult problem facing the programme because of poor education, bad educational experiences and other conditions related to poverty. In 1968, 92% of the Lummi community had less than an 8th grade education (Hood, 1971).

The Lummi Aquaculture Training Programs were conducted over a 3-year period in three separate programmes, each of which operated on a calendar-year basis. A total immersion approach was used in which trainees were expected to participate 8 hours/day, 5 days/week for an entire year. The federal MDTA (Manpower Development Training Act) provided trainees with weekly stipends to support their schooling. Project funding was provided annually, subject to reviews and critiques of training programme design, budgetary proposals, day to day operations and overall mission accomplishment. These evaluations were conducted primarily by the various levels of state, regional and national MDT offices (U.S. Department of Labour).

I wish to acknowledge the Lummi Indian Aquaculture Trainees and staff who provided the courage, tenacity and community spirit which contributed significantly to the Lummi Indian Aquaculture Project. Special credit goes to Mrs. Jeannette Casimir for her great patience, perserverance and skill which were essential to the success of the training programmes. I also wish to acknowledge Dr. W. G. Heath for inspiring and directing the initial Lummi efforts; Messers. Richard Poole, Alvin Casimir and James Ellis for special efforts to provide practical experience for trainees; the Lummi Indian Tribal Council and the Lummi Community for consistent support and encouragement; the U.S. Department of Labour, the Office of Economic Opportunity, the Economic Development Administration, Washington State Employment Security Office and the Oceanic Institute of Hawaii for financial support.

ATP-I

The first Aquaculture Training Programme (ATP-I) began in August 1969 and was initiated with the selection of 18 Lummi Indian trainees, representing a wide variety of educational backgrounds, vocational experiences and ages (Table 1). No prerequisites other than interest were made for enrollment in the programme. For the first 8 weeks, intensive classroom, laboratory and field work covered a side range of topics including basic biology and chemistry, remedial math, fish and shellfish taxonomy and ecology. Trainees were then assigned on a rotational basis to 'on the job training' sites throughout Washington State for periods up to 10 months. These sites consisted of cooperating government and private establishments involved in some aspect of aquaculture (Table 2). The trainee class was divided into two separate rotational sequences. The first group consist of 4 teams of 3. Each team rotated among 4 of

TABLE 1. *Age and Educational Background of ATP Trainees*

Programme	No. trainees completing	Age range (yrs.)	Range of educational background
ATP-I	18	18-40	10th - 12th Grade
ATP-II	57	17-65	5th - 12th Grade
ATP-III	46	18-65	8th - 12th Grade

the 6 training sites, spending approximately 2½ months at each facility (Table 2). Trainees spent about 20-40% of their time with classroom oriented activities and applied themselves more (80-60%) to laboratory and field activities. The second group consisted of 2 teams of 3, each of which spent the entire 10 month period at a single station (Table 2). They spend approximately 40-50% of their time in classroom sessions and the remainder on practical applications in the laboratory and field.

Increased support at the federal and state levels resulted in centralization of the entire training programme on the Lummi reservation with increased cohesiveness and improved continuity within curriculum. New facilities included : three laboratories (Fish Disease and Microbiology, Water Quality Analysis, Experimental Fish Hatchery) and a lecture hall.

In addition, existing facilities such as the Lummi Oyster Hatchery, the 700+ acre marine rearing pond (Fig. 1), and the Lummi holding and research ponds, were heavily used by the training programme.

TABLE 2. *On the job training sites ATP-I*

Site	Activities
Lummi Oyster Hatchery (Lummi Indian Tribe, Lummi Island, Washington)	Oyster conditioning and spawning, rearing ; Unicellular algal culture ; hatchery maintenance and sanitation.
Western Oyster Company (Private, Purdy, Washington)	Oyster planting, harvesting Oyster processing and grading Oyster raft maintenance
R/V Brown Bear (NMFS, Manchester, Washington)	Oyster rearing Salmonid mariculture Water quality monitoring
Quilcene National Fish Hatchery (U.S. Bur. Sports Fisheries and Wildlife, Quilcene, Washington)	Salmonid fish feeding and maintenance Artificial spawning Salmonid egg and larval rearing ; hatchery maintenance
Western Fish Disease Laboratory (U.S. Bur. Sports Fisheries and Wildlife, Seattle, Washington)	Fish disease detection Disease prevention and treatment, fish pathology
Western Fish Nutrition Laboratory (U.S. Bur. Sports Fisheries and Wildlife, Cooks, Washington)	Fish anatomy, physiology Diet preparation, evaluation Feeding techniques, nutritional diseases

ATP-II

The progress of the Lummi Indian Aquaculture Project during 1969-1970, the successes of ATP-I, the determination and experiences of the ATP-I trainees and the likelihood of future employment, all served to greatly increase the interest in aquacultural training. ATP-II began in October 1970 with sixty-four new Lummi Indian trainees, who were selected out of a list of over 200 applicants.

The centralization of the entire training programme on the Lummi reservation increased the effective contact time between trainees, instructors and the training programme itself. Importantly, it also increased the opportunities of trainees for 'hands-on' experience on their own reservation, including the developmental aspects of the entire project. The curriculum was also greatly expanded in coverage and depth from that of the previous program (Table 3).

For the first six months, trainees spent 50% of the time in daily, 4 hour morning classroom sessions consisting of lectures, group discussions, and exercises. Such classroom activities were taught in the immediate context of fish and shellfish culture operations *on the reservation*. The remainder of the day was usually spent on laboratory and/or field exercises. During the final 6 months of ATP-II, morning class sessions were reduced to about 2-3 days/week with at least 75% of the time being devoted to one of several assigned group projects (Table 4).

A key aspect to the ATP-II was the assignment of the corps of more experienced assistant instructors (ATP-I graduates) who in turn assigned a team leader from among those trainees assigned to a particular project. Specific project responsibilities and duties were also assigned by the project supervisor with assistance of the team leader and consultation of the professional instructional staff. Increasing responsibility was placed on the individual trainees. This was aided by the partial rotation of team leaders and the designation of other individuals to undertake numerous special assignments such as the participation in other tribal affairs on behalf of class members, minority education panels by various colleges and universities, and state and federal regional meetings dealing with vocational training and Indian education. Trainees were also given opportunities to attend several scientific meetings involving aquaculture.

Aside from regular lectures (two times/week) to the class and to specific group project teams, the function of the professional instructional staff was gradually reduced primarily to budget administration, general advisement and supervision of the various research projects, as more and more of the burden of class and individual research project responsibilities were placed on individual trainees.

ATP-III

In October 1971, an *Advanced* Aquaculture Training Programme (ATP-III) was begun with the enrollment of 46 trainees, most of whom were graduates of previous training programmes. The immediate goal of this programme was to expedite the development of potential supervisory and instructional personnel. Thus, an even greater emphasis on independent and creative thought, leadership and individual responsibility was made in ATP-III. Important routine operations of the Lummi Project such as the gathering and calculation of growth data from fish and oyster stocks, became the responsibility of the trainees. The advanced trainees formed the nucleus of a staff that helped to perpetuate and pass on the training and experience to future workers in the project. The establishment and perpetuation of the technological and scientific expertise within the community is key to the long term survival of the project. It is the ' missing nail ' (Brown, 1971) that has historically not been a part of many efforts to better conditions in poor societies through innovative science and technology.

Increased trainee responsibilities included the maintenance and supply of equipment and supplies, partial budgetary administration, supervision of group projects and the coordination of vehicle and equipment use. Disciplinary and grievance problems were also handled mainly by trainees. Academically, the main emphasis was on group projects (Table 4). Twice a week regular class lectures on specific topics on aquaculture were made by instructors. Periodic trainee seminars, review sessions similar in content to those of ATP-II, were conducted. Small group lectures and demonstrations by instructors specific to and for those involved with a particular project were a frequent part

TABLE 3. *ATP-II, III Curriculum*

Topic	Elements covered
Remedial Math	The four fundamental operations; fraction, decimal, ratio-proportions, per cent, metric system
Remedial Reading	Selected reading assignments
Study Skills	Study habits, note taking and organization
Introduction to Chemistry	Atomic, molecular theory; ions, dissociation, simple chemical reactions related to study of biological systems and water quality
Introductory Zoology	Animal diversity, cell theory, organ system structure, function
Aquatic/Marine Ecology	Bio-geochemical cycles; trophic relationships, zonation of the sea; estuarine circulation and other physical processes. Habitats, niches, populations, communities
Fisheries Biology	Fish anatomy, fish ecology and life cycles, nutrition, disease, hatchery techniques, artificial spawning, larval rearing
Shellfish Biology	Bivalve taxonomy, anatomy, ecology and life histories. Shellfish conditions, spawning, larval rearing, unicellular algae culture
World Aquaculture	Oyster, clam culture; Tropical, temperate fish culture; Disease, predation, pollution, selective breeding, current event, special topics

TABLE 4. *ATP Group Research and Other Projects*

Programme	Activities
Marine Ecological Survey	Monitor physico-chemical, biotic environment in 700 acre sea pond and adjacent area; monitor marine pollution sources of industry.
Nooksack River Drainage Study-I	Monitor physico-chemical, biotic environment in Nooksack River. Monitor industrial and agricultural pollution sources.
Oyster Hatchery Operations	Oyster culture techniques and procedures, Algae culture. Hatchery sanitation, maintenance.
Fish Disease Study Group	Methods of fish disease. Detection and diagnosis; disease treatment and prevention; microbiological techniques and procedures.
Fish Diet Studies*	Feeding trials, growth data collection and evaluation. Diet conversion efficiency calculation. Hatchery maintenance, sanitation.
Nooksack River Drainage Study II**	River Volume monitoring. Lummi Bay, 700 acre sea pond circulation pattern studies. Heavy metals, pesticide level sampling, coliform bacteria monitoring.
Fish Hatchery Operations	Fish culture techniques and methods; hatchery sanitation, maintenance.
Food Habit Study of Indigenous Fish in the Rearing pond	Diet study of Starry flounder (*Platichthys stellatus*), Staghorn sculpin (*Leptocottus armatus*) from sea pond.
Comparative Growth Rates of Oysters (*Crassotrea gigas*, *Ostrea edulis*) in the sea pond	Growth rate monitoring at selected sites in sea pond.

* ATP-II only.
** Joint Research Project with U.S. Geological Service, Bureau of Indian Affairs.

of the curriculum. These activities were co-ordinated and conducted mainly by selected trainees.

In achieving the goals of the three Lummi Aquaculture Training Programmes, (ATP I, II, III) numerous problems were encountered. A wide range of educational backgrounds, the common occurrence of poor reading and mathematical ability, were major obstacles. To alleviate these, reading assignments were selected according to ability and small reading groups were conducted on a regular basis (8-12 hours/week) in which assistant instructors, instructors, or the more skilled readers assisted in vocabulary development and reading comprehension through discussions. Remedial math groups were similarly organized in which trainees regularly participated in programmed math exercises selected according to individual ability. However, these measures did not, nor could they be expected to, completely solve these shortcomings in the educational background of many Lummi Indian trainees. There were noticeable differences in improvement between those who had not used reading and math skills for many years and those who had. Nevertheless these measures were regarded as very useful since performance of all trainees improved.

The use of small groups and individual reading assignments encouraged individual verbalization of abstract ideas through questions and discussion among peers who also served as group leaders and assistant instructors. This opportunity was very important since most Lummi Indian trainees usually have been hesitant about open questioning of a teacher of those in 'authority'. This is probably related to the numerous unpleasant past experiences many, especially the older trainees, have had in existing public school systems. Since the ability to question is essential to problem solving, considerable attention was given towards the development of this attribute with excellent results. The initiation and maintenance of a completely informal atmosphere where instructors and other supervisory personnel were seen as ordinary and fallible individuals were also steps in the direction. This informality was extended to the actual communication of scientific ideas and concepts with excellent results. An example of this was the extensive use of 'Lummi colloquialisms' with a minimum of scientific terminology in initial lectures and discussions. After mastering an idea, the use of scientific jargon was then introduced and encouraged.

Independent thought, cooperation and responsibility were strongly encouraged through the scheme of peer supervision and lecturing in all group projects. Had this not been done, many if not most trainees, might have remained reserved or shy about questioning, discussing and making suggestions in their work. In addition to the applicability to the on-going Lummi Indian Aquaculture Project most group research or field projects were selected for providing instant gratification through immediate results or productive physical activity. This was important in the development of trainee attention span. Trainee evaluations were based on improvement in written and practical examinations, project reports, performance in real situations, initiative and attendance.

Approximately 90% of all trainees completed the training programme over the three training programmes. They significantly augmented the work force of the aquaculture project. Virtually all of the technical laboratory and field operations were conducted by graduates of the ATP's.

Summary

In summarizing, the impact of the Aquaculture Training Programmes on the Lummi Indian Tribe has been very significant. Despite major obstacles such as poor educational backgrounds, it has successfully provided the

academic background and training for the technicians of the Lummi Aquaculture Project. In the process, it has also greatly enhanced the opportunities for better education for the Lummi community. While attending ATP-II, ATP-III, 14 Lummi trainees obtained General Equivalency Diplomas (G.E.D.). In addition, two trainees met requirements for high school diplomas (Ferndale High School, Ferndale, Washington) through completion of training in ATP. Between 1969 and 1972, college and university enrollment of Lummi Indians increased from 3 to 48. During this period, 1969-1972, there appeared to be a decline in the number of high school dropouts from the Lummi community (ca 50%). There was a significantly more positive attitude among the Lummi towards education which was partially due to psychological influence of the Lummi Aquaculture Project and the Aquaculture Training Programmes.

Although the project and its training programmes were innovative and consistent with Lummi Indian culture, the driving force behind the high degree of success attained was the tremendous community motivation, cooperation and support. The successes earned by the Lummi community in the face of great controversy and pessimism by skeptics in the public, private and government sectors have served to stimulate an even greater desire for better socio-economic and educational opportunities on the Lummi Indian reservation. Importantly, the Lummi tribe has learned to effectively work within the confines of government bureaucracy to attain their goals. The aquaculture training programmes have evolved to the point where it is presently being considered for accreditation as a specialized community college for Native Americans.

In the organization and functioning of a system of science education in a socio-economically depressed environment, as described above, the wide use of student peers in instructional and supervisory roles can be of great value. These individuals are often those who can best relate ideas more effectively than outside instructors. The use of members of the community in administration and counselling is important. Another significant factor is the total immersion approach in an atmosphere of informality and flexibility. Finally, a commitment by instructors or teachers towards visualizing the world from the point of view of those being taught is essential.

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RECENT OBSERVATIONS ON PHYSICO-CHEMICAL CHARACTERISTICS OF THE LAGOON ALONG THE PALK BAY AT MANDAPAM WITH A NOTE ON THE POSSIBILITY OF ITS UTILIZATION FOR LARGE SCALE FISH CULTURE

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ABSTRACT

The paper deals with the physico-chemical characteristics of water in the Pillaimadam Lagoon along the Palk Bay and their relationship with variations in the abundance of fish seed in the lagoon. Seven stations have been fixed covering the vast expanse of the lagoon and one at the bar mouth in the sea for collection of data at fortnightly intervals. Detailed observations have been made on variations in depth, direction of the movement of water in and out of the lagoon, atmospheric and surface water temperature, salinity, dissolved oxygen and pH from October 1978 onwards. In addition, data on the rate of evaporation, seepage and the effect of tidal influence on the depth of the water in the adjacent fish farm are also included.

In general, the physico-chemical characteristics of the water in the lagoon from October to March have been found to be different from those during the period April to September. During the former period, the Palk Bay remains rough with the connection to the lagoon well established, rain water entering into the lagoon from the land-ward sides mainly during the North-East monsoon period (October-December), whereas in the latter period, the connection to the sea is cut-off resulting in altogether different conditions.

The present observations have been compared with previous observations on the lagoon. The relationship between the physico-chemical characteristics of the water and the variations in the abundance of fish seed in the lagoon has been studied. The data indicate that fishes like mullets, milkfish and prawns, the seed of which is abundant in the area, could be cultured in the lagoon with the application of suitable management practices.

INTRODUCTION

IN THE RECENT PAST, emphasis is being laid on the development of aquaculture to increase fish production in fresh water, backwaters, brackish water lakes, lagoons and coastal waters in different parts of the country. Before any large scale culture of fish is attempted in an area, it is necessary to know the topography, physico-chemical and biological characteristics of the area concerned. With this objective, Tampi (1959) gave an account of the ecological and fisheries characteristics of the salt water lagoon near Mandapam. In view of the recent proposal to develop the lagoon into a fish farm by the Central Marine Fisheries Research Institute, the hydrological conditions and the availability of fish seed in the vicinity for large scale culture have been studied during the period October, 1978 to September, 1979. The results of this study are presented in this paper.

DESCRIPTION OF THE AREA

Location

Pillaimadam lagoon (long 79°06′E ; lat 9°15′ N) is situated along the coast of Palk Bay, in the vicinity of Mandapam. The lagoon has a rectangular shape, its long axis being parallel to the coast. It is connected to the sea by a narrow bar mouth (Fig. 1). The lagoon is connected to the river Vaigai on its western side only in the rainy season. During the North-East monsoon months of October, November and December vigorous waves associated with high tides break the sand bar and establish the connection with sea. The lagoon covers a vast area of about 360 hectares (Tampi, 1969) and forms a saline habitat enabling fish seed like those of mullets, milkfish, prawn, *etc.* to enter and grow for certain periods. For most of the year, except monsoon months mentioned above, the entire lagoon remains isolated as a vast shallow saline pool. In pre-monsoon months (July-September), the entire area gets dried up due to high evaporation and lack of connection with the sea.

Air temperature

The hottest months in the area are April to June when the maximum air temperature reaches 32.76°C. Colder period extends from October to December, the minimum temperature being 26.22°C.

Rainfall

The total annual rainfall of this region is about 1235 mm (Fig. 1) most of it falling during North-East monsoon months.

Seasons

With reference to the North-East monsoon, it is convenient to divide the year into the following four seasons for understanding hydrographical changes in the area and their relation to fishing activities.

Monsoon	:	October, November and December
Post monsoon	:	January, February and March
Summer	:	April, May and June
Pre-monsoon	:	July, August and September.

Material and Methods

During the period October 1978 to September 1979, observations on physico-chemical characteristics of the lagoon were made at fortnightly intervals in the morning hours between 6.30 and 8.30 hrs. Eight stations were selected, one of them at the bar mouth in the sea representing oceanic conditions and all the others in the lagoon (Fig. 1) covering the entire area of the lagoon. Surface water samples were collected from these stations using a plastic bucket and analysed for salinity, dissolved oxygen and pH by the methods outlined by Strickland and Parsons (1968). The monthly mean value of each parameter for stations 1 to 8 as well as average values of all lagoon stations 2 to 8 were taken and plotted (Fig. 2). Data on the rate of evaporation in the lagoon for the period July to September (Pre-monsoon), seepage and the effect of tidal influence on the depth of the water in the adjacent fishfarm for the months August and September are also included (Fig. 3). Rate of evaporation was calculated using the formula (Etter, 1976)

$$E = \frac{0.621\ P_a\ c_E\ (e_s - e_a) W}{Pa}$$

where e_a is the saturation vapour pressure of air, e_s is the saturation vapour pressure of air over sea water, Pa is atmospheric pressure, Pa is density of air, W is wind speed at 10 meter level and c_E is dimensionless coefficient of latent heat transfer.

Results

Hydrographic characteristics

The hydrographic characteristics in the lagoon are best described with reference to the four seasons mentioned above.

Monsoon

During the monsoon period (October-December) the lagoon receives large amounts of flood

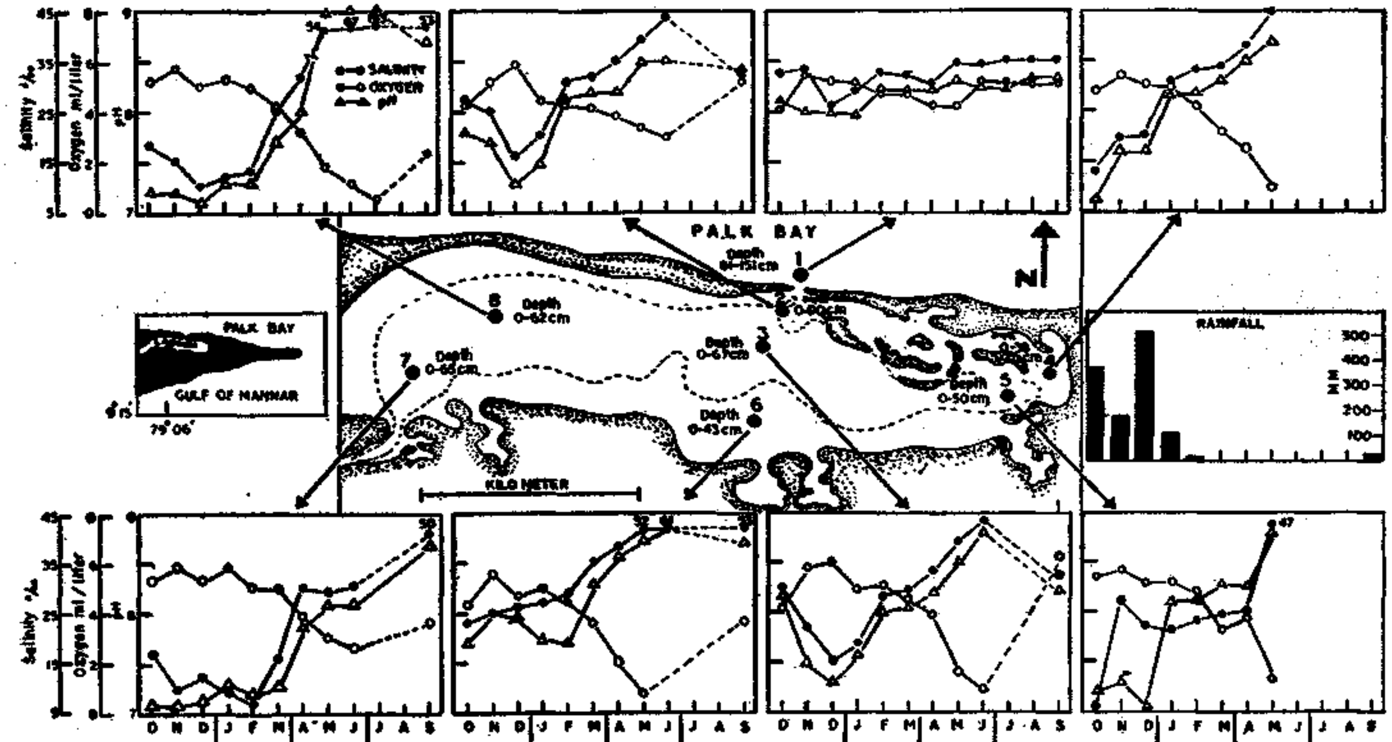

Fig. 1. Pillaimadam lagoon near Mandapam (Southeast coast of India) indicating the location of eight observation stations, variations in physico-chemical characteristics at individual stations and data on rainfall.

water from the river and run off water from the surrounding land on the southern side of the lagoon. Towards the end of October, when the monsoon commences, the connection to the sea is established. Consequently, sea water rushes into the lagoon creating certain special conditions at this time. It is obvious, from field observations made at station 2 on the direction of the movement of water, that water flows from the lagoon into the sea, this process prevailing upto the end of the period.

Surface water temperature during the period varied between 27.07°C and 29.70°C. The air temperature was almost same as the surface water temperature. The surface water temperature in the lagoon was slightly lower (28.10—29.75°C) than that of the inshore station 1. This may be attributed to the influx of colder fresh water from the river Vaigai and run off water from the land.

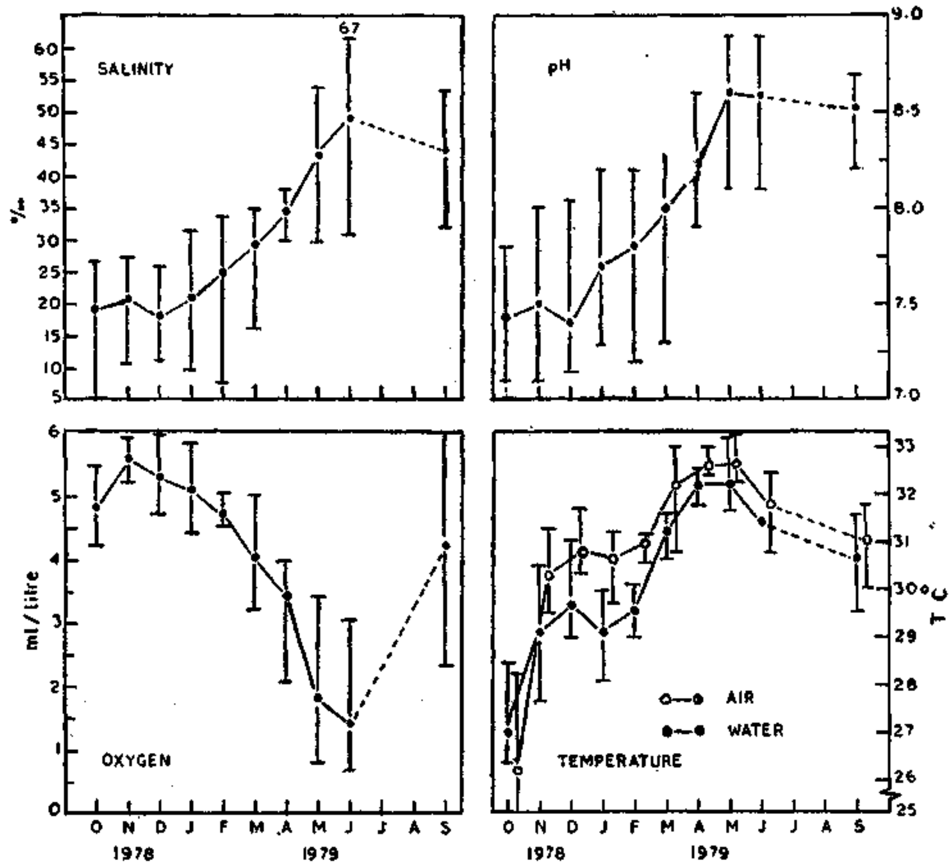

Fig. 2. Range and mean values for salinity, dissolved oxygen, pH and temperature (air and surface water).

Salinity variations in the lagoon (18.16—21.22‰) were considerably lesser than at sea (26.65—32.64‰): minimum (5.85‰) occurred at station 7 because of mixing of river water and maximum (26.86‰) at station 2 because of seawater flow. The total annual rainfall in this region was estimated to be 1235 mm, most of it falling during this period. As a result of it, a reduction in salinity was observed in almost all stations. In addition, the river water along with run off water from the land reduces the salinity further, though the soil of the lagoon contains salt deposits stored in summer. The pH varied between 7.38-7.69.

Generally, dissolved oxygen content in the lagoon was observed to be more than that at the inshore station. More or less similar values in dissolved oxygen content were recorded at all stations throughout the period and a steady increase of the same was noticed from October to December.

Post-monsoon

The tidal effect was more pronounced during this period (January-March). This is of considerable biological significance and is greatly responsible for controlling physico-chemical characteristics in the area during the period (Tampi, 1959). Towards the beginning of post-monsoon, when the North-East wind is strong, seawater rushes into the lagoon. As a result of this process, oceanic conditions prevail in the lagoon also, particularly of temperature, salinity, oxygen and pH.

Surface water temperature in the lagoon ranged from 29.10 - 31.24°C while it ranged from 29.00 - 31.25°C in the sea. There is a slight deviation in the temperature curves as surface water temperature differs from air temperature from January onwards due to the blowing of dry wind.

Salinity values at stations 2 - 6 were uniform throughout the period (Fig. 1). Variation in salinity is accompanied by variation in pH which ranged from 7.69-8.03. A slow decrease in dissolved oxygen content was noticed from January (5.11 ml/l) to March (4.02 ml/l) and this drop in oxygen content may be due to the absence of strong winds thus decreasing the solubility of atmospheric gases associated with increasing surface water temperature (31.24°C) as summer approaches by the end of March.

Summer

The period extends from April to June during which the maximum temperatures of air (32.67°C) as well as of water (32.20°C) were recorded.

From April onwards, a steady increase in salinity (34.65—49.23 ‰) above normal condition at sea was noticed at all the stations as the bar mouth gets closed. Due to the prevalence of high South-West wind and to the rather high atmospheric temperature, there is a certain amount of evaporation which causes the rise in salinity of the shallow lagoon and that of the inshore during the period (Jayaraman, 1954). Consequently, small saline pools were formed. With the rise in salinity, pH showed marked changes (8.26 - 8.61). A steady decline in dissolved oxygen content occurred from April onwards reaching a minimum (1.469 ml/l) by June. Tampi (1959) attributed the low level of oxygen to organic decay during the dry summer months, increase in temperature and the absence of strong wind.

Pre-monsoon

From July onwards, the entire lagoon remains dry except at station 8 where a pocket of water stands. This condition prevails upto the commencement of next monsoon. Hyper saline conditions were observed only in the month of July at station 8 (193.63 ‰) with simultaneous rise in pH to 9.00 and no dissolved oxygen at all. The absence of dissolved oxygen content in the small body of water at station 8 can be attributed to the liberation of hydrogen sulphide during the process of organic decay observed at the station. In the beginning of September, salinity of the water in the lagoon varied from 50.48 - 53.48 ‰ at stations 6 to 8 when there was little rainfall. Towards the end of September, salinity gradually decreased due to the influx of some rain water.

Rate of evaporation

Evaporation rate in the area has been calculated for a period of three months (July, August and September) as the whole area of the lagoon begins to dry up from July onwards. The maximum value was obtained in August (2.289 cm/day), the values for July and September being 1.495 and 1.55 cm/day respectively. The excess evaporation during August may be attributed to the prevalance of dry South-West wind accompanied by heat liberated from the dried salt deposits.

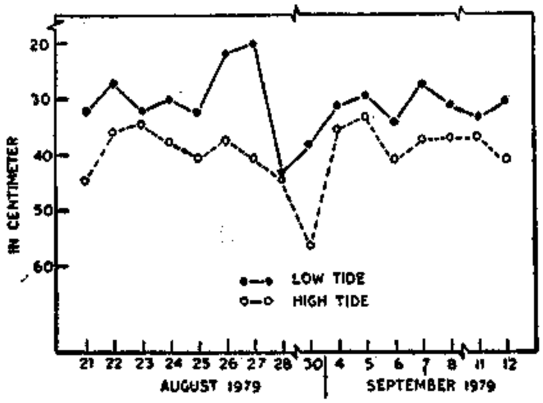

Fig. 3. The influence of high and low tides on the depth in a fish pond adjacent to the lagoon.

Influence of tides on the depth of water in coastal ponds

Observations on the variations in depth of the water in the adjacent fish farm with reference to the tides were made during the months of August and September. Experiments were conducted in one of the culture ponds with an initial water level of 32 cm. Daily variations in the water level at high tide as well as low tide were recorded (Fig. 3). Data indicate that there is an increase in water level in the pond to 56 cm at high tide and a decrease to 21 cm at low tide.

Relationship between the physico-chemical characteristics of the water in the lagoon and variations in the abundance of fish seed

Survey of the fish seed resources in and around the lagoon indicated the occurrence of abundance of the fry of mullets *Ellochelon waigiensis* (most abundant: 10.8 to 85 mm), *Liza macrolepis* (10 to 105 mm), *Valamugil seheli* (13 to 44 mm), *Therapon* sp. (20 to 30 mm), *Chanos chanos* (40 to 80 mm), *Sillago sihama* (50 to 80 mm), *Tachysurus thalassinus* (50 to 80 mm), *Nematolosa nasus* (60 to 90 mm), *Leiognathus brevirostris* (30 to 40 mm), *Hemirhamphus* sp. (17-23 mm), gobids (30 to 40 mm) and belonids (80 to 102 mm). Prawn seed was represented by *Penaeus indicus* (25 to 30 mm) and *Metapenaeus burkenroadi* (30 to 50 mm). Quantitative studies revealed that greater quantities of fry and juveniles were available in January, February, May, June and November. These observations indicate that seed of commercially important species of fishes and prawns could be collected in the vicinity of the lagoon itself for large scale culture of the same in the lagoon by the development of the lagoon into a suitable fish farm.

Discussion

In general, in all the stations in the lagoon during monsoon salinity has been found to be low ranging from 10.63‰ to 30.26‰ thereafter the values of salinity have been found to increase gradually upto a maximum of 67.50‰ in June. However, at station 7, salinity has been generally found to be lower than the other stations, ranging from 7.50‰ to 30.50‰, which is attributed to the fact that this station is located close to the river mouth. At station 8, hypersaline condition (193.63‰) was noticed in the month of July. In the month of September, although salinity values showed a decrease from June (in July, August the lagoon dries up) the values are higher than those for normal sea water, probably because the salt deposits are washed by the rains during this month as well as their dilution by the influx of sea water through the bar mouth. Dissolved oxygen values were high during monsoon and post-monsoon months ranging from 3.238 to 5.94 ml/1 whereas in summer and pre-monsoon months, the values were lower, ranging from 0.673 to 3.959 ml/1 except stations 2 and 3 when the values were found to be 5.210 and 6.215 ml/1 respectively in the month of September which are attributed to fresh showers of rain.

The pH values in the monsoon season and the beginning of the post-monsoon season were generally low, ranging from 7.10 to 8.20 whereas in the rest of the post-monsoon, summer and pre-monsoon season, the pH values were generally higher ranging from 7.20 to 8.94.

Atmospheric temperature showed a gradual increase from October to August declining thereafter to a minimum in October. Water temperature also showed a similar trend except that the values were lower than those of the air.

In the sea station, salinity values showed a gradual increase from December (26.65‰) to August (32.39‰) thereafter the values declined; the dissolved oxygen values were higher in the months November to January (5.115 to 5.534 ml/1), lower from February to May (4.703 to 4.22 ml/1), raising again with a range of 5.109 to 5.257 ml/1 from June to September. In October the value was 4.76 ml/1 ; the pH values ranged from 8.02 to 8.30. Air temperature varied from 28.25 to 33.00°C and water temperature gradually increased from October (28.00°C) to May (32.15°C).

Consequently, the cyclic pattern of changes in the lagoon during the year may be briefly stated as follows :

(i) Estuarine conditions prevail during the monsoon as there is free admixture of fresh water and sea water.

(ii) Near oceanic conditions occur throughout the post-monsoon as only sea water rushes into the lagoon.

(iii) Saline pools are formed due to shallowness of the lagoon and excess evaporation during summer, when the lagoon remains completely cut off from the sea.

(iv) For most part of pre-monsoon, almost the entire area of the lagoon gets dried up leaving salt deposits in some places.

One of the major factors controlling the biological productivity is salinity in the area (Tampi, 1969). The wide annual range in salinity from 18.16‰ to 193.63‰ with related fluctuations in pH and dissolved oxygen may have a combined effect on productivity. Quantitative studies revealed that greater quantities of fry and young ones of commercially important fishes were available in January, February, May, June and November when environmental conditions appear to be suitable for them. At other times, there is scarcity of fish seed, evidently due to unfavourable conditions.

Tampi (1969) estimated the rate of primary production in the lagoon to be in the range of 0.08 gC/m^3/day and 0.125 gC/m^3/day which is poor when compared with the production rate in Palk Bay, 0.435 gC/m^3/day (Nair *et al.*, 1973). In a series of fertilization experiments with artificial manures, Udaya Varma *et al.* (1963) made attempts to increase the basic production rate in fish ponds adjacent to the lagoon and found that production in the ponds improved from 0.106 gC/m^3/day to 0.955 gC/m^3/day after adding inorganic fertilizer (superphosphate). However, he concluded that the productivity of the ponds does not depend entirely on the nutrient salts, but that intensity of light and salinity may influence the productivity to a large extent.

It is proposed by the Central Marine Fisheries Research Institute to convert the saline coastal lagoon into a fish farm for large scale fish culture. Based on earlier observations and the present study, the problems which have to be solved in this connection are controlling the wide range of salinity, improving the level of organic production by suitable methods and increasing the depth in certain parts of the lagoon by various management practices.

The abundance of fry and young ones of commercially important species of fishes like mullets and milkfish and prawns in and around the lagoon especially in the months February, May and June also in other months makes stocking of the ponds easy and inexpensive for large scale culture of fishes in the area.

Tampi (1959) estimated an annual fish production of about 20 metric tons from the lagoon based on wild stocks. He stated that a production rate of 212 to 455 kg/hectare was obtained in the adjacent fish farm for milkfish. However, based on productivity studies, Tampi (1969) indicated that the theoretical yield of fish from the lagoon would be about 11 tons. The higher production rates of fish from the lagoon based on wild stocks may be explained by the fact that large number of fishes enter the lagoon when the connection to the sea is established, thus contributing to the catches. Although the lagoon is known to be not very productive, its productivity may be improved by adopting modern fish farming techniques aided by the free flow of sea water through the bar mouth, entry of fresh water from the river and the possibility of run off from landward side carrying nutrients.

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AN APPRAISAL OF THE PROSPECTS FOR AQUACULTURE IN THE MAVINAHOLE ESTUARINE TIDAL CREEK, KARWAR

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Abstract

The 8 km long ' Mavinahole ' estuarine creek, located near the mouth of the Kali River, forms a natural nursery and breeding ground for a variety of finfishes and shellfishes. This paper presents data on the hydrological characters, the analysis of bottom grab samples, experimental fishing operations, all of which reveal the abundance of a wide range of cultivable species, their tolerance to widely varying physico-chemical conditions. The results thus obtained, on the rich floral and faunal associations, the deposition of organic silt and sedimented clay, the tidal mud flats, the mangrove vegetation, halophytic grasses, dense epiphytic algal growth, variety of planktonic forms and the abundance of post larvae, frys, spats and juveniles of commercially important fishes and shellfishes, suggest that ' Mavinahole ' has all the characteristics of an ideal ecosystem with great promise for aquacultural activities.

Introduction

The raising of organisms in the aquatic environment has received considerable attention in recent years in view of its importance to augment the food requirements of the explosive world population. However, aquacultural practices in India are at the initial stage, although endowed with vast stretches of brackishwater areas, tidal inlets and swamps, sheltered coves and bays suitable for rearing commercially important prawns, molluscs and fishes. The Uttara Kannada district of Karnataka State, has a number of extensive estuarine systems, of which the Kali estuary situated at the northern boundary offers an excellent biotope for a variety of euryhaline forms. The low-lying areas on either side of the estuary offer ideal niches for culture of estuarine and inshore forms. It is in this context, the present study was taken to assess the culture potentialities of Mavinahole Creek (14°15'N - 74°07'E) a characteristic component of the complex and dynamic Kali river estuarine system.

Material and Methods

The present study, involved fortnightly field observations and collections at selected stations (Fig. 1) during January-October, 1979. Diurnal observations and sampling were also carried out at monthly intervals. Plant and animal populations, their habitat, *etc.* were recorded. Water samples were analysed following standard titrimetric methods.

Sampling for bacterial study was done in sterilized 250 ml bottles and 'Tryptone- Glucose Extract Agar ' method was adapted for obtaining the total plate count. Plankton samples were collected using a planktor net, while for benthic sampling, a Van-Veen type hand grab, suitable for shallow water operations, covering an area of 20 × 16 cm was used. Experimental fishing was done with drag and cast nets. The tidal amplitude was measured by means of a graduated wooden pole fixed vertically at the study sites.

Results and Discussion

Physiography and Hydrology

The creek extends to a length of about 8 km with an average depth of 0.8 m at high tide. The adjacent areas are widespread and most of which are lowlying paddy fields. The large tidal amplitudes (-0.03 to +2.0 m) was a dominant factor which decreased in intensity with increasing distance from the estuarine main axis (Station 2 - 1.7 m, Station 6 - 1.1 m). Large areas at the intertidal zone were exposed during spring low tides and the creek with gentle water movements, with its component mudflats, mangroves, halophytic marshgrasses, rich epiphytic algalgrowth, variety of planktonic forms and diverse benthic populations constituted the breeding and nursery

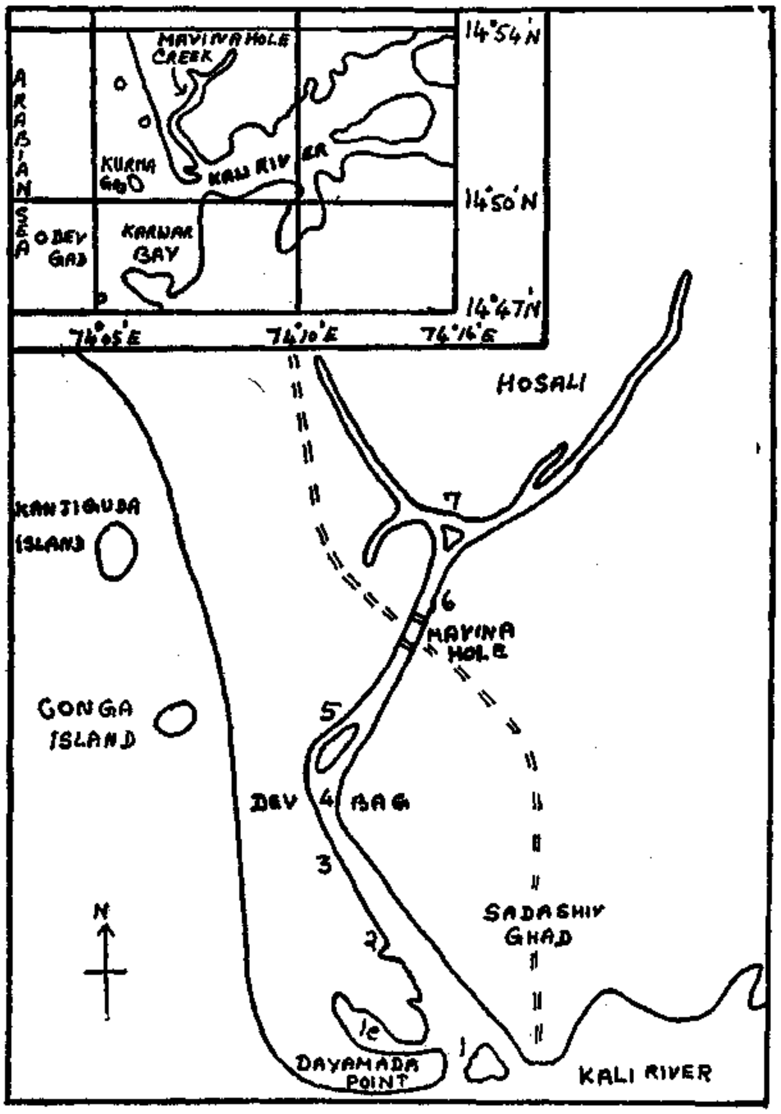

Fig. 1. Map of the Mavinahole Creek area showing the study sites.

grounds for a number of shellfishes and finfishes.

Consistent with the estuarine origin, the creek experiences fluctuating hydrological features, much so during south-west monsoon (June-September), after which the conditions stabilized through the short post-monsoon (October-December) period and attained more definable entities during the pre-monsoon (January-May) period (Table 3, 4, 5).

Flora and Fauna

From the high bacterial population of the sediment-water interphase with a count of 42,000-90,000/m (January-May) and 7,800-17,600/m (June-October), it was evident that it played a significant role in detritus formation and nutrient release.

TABLE 1. *Monthly plankton composition (qualitative)*

PLANKTON	MONTHS									
	J	F	M	A	M	J	J	A	S	O
Coscinodiscus sp.	+	—	—	+	+	+R	+R	—	+A	+A
Chaetoceros sp.	+	—	+A	+A	—	—	—	+	—	—
Thalassiosira gravida	—	+A	—	+	+A	—	—	+	+	+A
Biddulphia sp.	—	—	—	—	+	—	—	—	—	—
Pyrocystis sp.	+	+	+	—	—	—	—	—	+	+
Ceratium tripos	+	+	+	—	+	—	—	—	—	—
Noctiluca miliaris	—	+A	+	+	+	—	—	—	+R	+R
Trichodesmium erethreum	—	+	+A	+	—	—	—	+R	—	—
Tintinopsis sp.	+	—	+	+	+	+	—	—	—	—
Favella sp.	—	—	—	+	+	+	—	—	—	—
Globigerina sp.	+	+	+	—	—	—	—	—	+	+
Ephyra larva	+	+	—	—	—	—	—	—	—	—
Sagitta elegans	—	+	+	—	—	—	—	—	—	+R
Copepods	+	+A	+A	+	+A	+R	+R	+R	+	+A
Penilia sp.	—	+R	+R	—	+R	—	—	—	—	+R
Evadne sp.	—	—	+R	—	—	—	+R	—	—	—
Penaeid post-larvae	+	+	+	—	—	—	—	+	+A	+A
Nauplius	+	+	+	+	+	—	—	—	+	+
Zoea	+	+	—	—	—	—	—	—	—	+
Cresis	+	—	—	—	+	+	—	—	—	—
Oikopleura sp.	—	+R	—	+R	—	—	—	—	+R	—
Fish eggs.	+A	+A	+A	+A	+A	+R	+R	+	+A	+

— = Absent +R = Rare
+ = Moderately present +A = Abundant

TABLE 2. *Monthly seed availability of cultivable forms*

SPECIES	MONTHS									
	J	F	M	A	M	J	J	A	S	O
Penaeus indicus	+	+	+	+	+	—	—	+	+A	+A
P. monodon	+	+	+	—	—	+	+	+A	+A	+A
Metapenaeus dobsoni	+	+	—	+	—	—	—	+A	+A	+A
M. monoceros	+	+	+	—	—	—	—	+A	+A	+A
Scylla serrata	+	+	—	—	—	+	+A	+A	+A	+
Mugil cephalus	+A	+	+	+	+	+	+	+A	+A	+A
Etroplus suratensis	+A	+A	+A	+	+	—	—	+	+	+
Scatophagus argus	+	+	+A	+A	+A	—	—	—	—	+

+ = Present moderately ; +A = Abundant

TABLE 3. *Monthly mean hydrological parameters*

Month		Temperature (°C)	Oxygen (ml/l)	Salinity (‰)
Jan.	..	28.0	5.761	29.22
Feb.	..	27.8	4.064	30.14
Mar.	..	28.3	4.000	30.11
Apr.	..	29.1	5.419	32.43
May	..	29.7	3.387	33.02
Jun.	..	27.5	5.927	2.22
Jul.	..	28.1	6.013	2.10
Aug.	..	28.6	4.164	6.82
Sep.	..	28.9	4.064	3.88
Oct.	..	29.0	4.062	19.94

The algal vegetation of the creek was mostly epibenthic, the dominant species being *Ulva reticulata* and *Enteromorpha plexiosa*, with the former having an extensive growth during the premonsoon, with a bloom occurring towards May and the latter in early pre-monsoon (January-February). *Halophylla ovalis* and *Halophylla buccari* were observed as dense, scattered patchy growth on the bed throughout the study period. The contribution of these algae to the maintenance of the ecosystem seems to be of considerable importance as observed for other similar biotopes (Tampi, 1959).

The mangrove vegetation was generally made up of the fringing type, except for the swamps located at stations 1 c, and 4 (Fig. 2). The dominant species were : *Rhizophora*

TABLE 4. *Diurnal fluctuations in hydrological parameters*

Season		Time	Temperature (°C)	Oxygen (ml/l)	Salinity (‰)	Tidal Phase
		5.00 A.M.	28.60	3.726	32.30	Low
Pre-monsoon	..	8.00 A.M.	29.50	2.726	32.32	
(May)		11.00 A.M.	32.10	3.387	32.91	High
		3.00 P.M.	33.15	2.371	33.21	
		5.00 P.M.	33.00	3.387	33.30	Low
		5.00 A.M.	26.00	4.160	4.22	Low
Monsoon	..	8.00 A.M.	27.80	4.820	3.83	
(Aug.)		11.00 A.M.	28.60	4.950	8.04	High
		2.00 P.M.	31.20	5.130	8.81	
		5.00 P.M.	30.50	4.900	5.02	Low

TABLE 5. *Seasonal Minimum and Maximum in Hydrological Parameters*

Parameter		Minimum		Maximum	
		Jan-May	Jun-Oct	Jan-May	Jun-Oct
Temperature (°C)	..	27.40	26.00	33.15	31.80
Dissolved Oxygen (ml/ltr)	..	2.37	4.16	5.76	6.01
Salinity (‰)	..	26.21	1.54	33.30	19.90

mucronata, *Avicennia* sp., *Sonneratia* sp., *Acanthus elicifolius* and Marsh grasses.

Planktonic forms (Table 1) was noticed to be abundant in the premonsoon period with a swarm occurring in the month of February. During the monsoon, they were sparsely distributed, whereas towards the late monsoon period, the population again showed an increase with conspicuous presence of post-larvae of penaeid prawns and fish eggs *etc.*

The benthic population consisted mainly of bivalves, polychaetes, gastropods, amphipods, isopods, mysids, coelenterates and crabs, many of which constituted food for the estuarine fishes. The premonsoon was characterised with a high biomass (16.13-190.3 gm/m^2) and macrobenthos count (59-371/m^2) as compared to the monsoon period with a lower biomass (3.1-73.0 gm/m^2) and macrobenthos count (30-263/m^2).

Experimental fishing operations have revealed the occurrence of juveniles of numerous benthic and nektonic forms, many of which were of culturable importance.

Mugil cephalus	*Penaeus indicus*
Teuthis vermiculata	*P. monodon*
Therapon jarbua	*Metapenaeus monoceros*
Etroplus suratensis	*M. dobsoni*
Scatophagus argus	*M. affinis*
Sillago sihama	*Scylla serrata*
Ambassis sp.	*Uca* sp.
Tilapia sp.	*Meretrix casta*
Plotosus arab	*M. meretrix*
Arius nenghus	*Paphia malabarica*
Triacanthus brevirostris	*Villorita cyprinoides*
Tetradon inermis	*Crassostrea madrasensis*
Anguilla sp.	*C. gryphoides*
Cynoglossus sp.	

Seed Resources

Seeds of variety of shellfishes and finfishes were seen to have a pronounced occurrence in these estuarine waters during the major part of the year (Table 2). The sheltered calm water areas among the reeds, tidal flats and mangrove swamps constituted ideal sites for collection of seeds ; the zones of their maximum occurrence being located at stations 4 and 7. The size of seeds ranged between 1.0-7.6 cm for penaeid prawns and 1.5-10.3 cm for *Mugil cephalus*.

CULTURE POTENTIALITIES

Present status

The occurrence of perennial nursery grounds and the nature of the fishery abounding in the creek have attracted quite a few entrepreneurs.

Large creek side impounding tanks 20×20 m with elevated bunds (1.0 m high) are used for trapping the fish within the tank by lowering a wooden sluice gate at the slack period of spring high tides. By this method, considerable number of seed prawns and mullets are captured.

Two small fish rearing farms (stations 5 and 7) are used for pond culture on a limited scale. The farm at station 5 with an area of about 4 acres has one sluice gate on the creek side and the main pond consists of eight 40 m long channels with a width of about 1.9 m and average depth of 0.8 m. Polyculture is practiced from September to May involving tidal stocking of mainly penaeid prawn and mullet seeds. Harvesting is done intermittently. As no proper management procedures are followed, the yield has been poor and consequently the farming has proved to be unprofitable.

The lowlying paddy fields adjacent to the creek where only paddy is grown at present, are provided with tall bunds and some of the fields are also provided with wooden sluice gates to keep away the saline water during the non-monsoon season and to let in the water during the monsoon when the creek water are nearly fresh.

The presence of predatory crabs — portunids, *Uca*; predatory fishes — *Therapon jarbua*, *Anguilla* sp., catfishes and gobioid fishes and the uneven bottom, pose some of the problems.

Future Prospects

The creek, between stations 1 and 3 with its organic rich sediment and a sandy-mud substratum is suitable for clam and oyster culture. The tidal pond (station 1 c) with an area of 4.6 acres, having a maximum depth of 1.6 m and a bottom of organic silt, clay and sand mixture can be utilized for polycultural practices.

The close proximity of the creek to the sea demands that due attention be paid in the future, whereby, with improved techniques, the post-larvae and juveniles of commercially important inshore water forms can be reared in large numbers within the creek, till they attain a suitable age, when they are periodically let out with the receeding tides to migrate back to inshore waters where they grow to their adult sizes and thus supplement the commercial fishery of the area (Nikolsky, 1963).

Culture in the lowlying areas adjacent to the creek having sufficient tidal influence, can be undertaken after some site preparation such as levelling, bund construction and fitting of sluice gates. Pumping also could be employed wherever the need is felt.

Aquafarming suitable to the rural economy can be undertaken by families either on a small scale for local consumption or on a commercial scale in this estuarine region. Pond culture for prawns and mullets can be taken up for a beginning. Application of improved culture methods would aid in stabilizing the aquaculture practice in this zone as, the ensured production through fish farming is of great importance, especially during the monsoon when the open sea and inshore fishing is suspended temporarily.

Yet, reclaimation of all this estuarine zone is not to be envisaged, as it would destroy a natural nursery of great significance. A rational balance is to be exercised between exploitation and conservation. As it is, fish farming in this region has a sound future, the only problem is of the time scale of development.

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A STUDY ON THE PHYSICO-CHEMICAL CHARACTERISTICS OF SOME BRACKISHWATER FISH POND SOILS OF WEST BENGAL*

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ABSTRACT

Important physico-chemical properties of the soils of some of the brackishwater fish ponds of West Bengal (India) were studied to assess their productivity and to identify the soil factors responsible for poor production. The results showed that texturally most of the soils belonged to silty clay loam group. pH values were slightly alkaline, which were considered to be favourable for good aquaculture, while low organic carbon content of the soils indicated necessity of organic manuring in such ponds. Fairly high free $CaCO_3$ content of the soils were considered helpful in counteracting some of the possible harmful effects of the suggested organic manuring of these ponds. E. C. values were high due to high concentrations of water soluble salts of cations dominated by Mg followed by Ca, Na and K and of anions dominated by Cl followed by SO_4, CO_3 and HCO_3 respectively. Amounts of total exchangeable bases were moderately high, which were dominated by Ca and Mg ions being followed by K and Na respectively.

INTRODUCTION

THE NATURE of bottom soil is considered to be of great importance in brackishwater aquaculture. Benthic algae, which form the main fish food organisms in brackishwater ponds, derive their nutrients either directly from the soil or from the soil-water interface, and accordingly, the productivity of such ponds depends largely on the nature and properties of the bottom soils. Pillay *et al.* (1962), in a study on ecology of benthic flora in some brackishwater fish ponds, observed that the algal productions in such ponds were correlated with the fluctuation in the nutrient status of the pond soils. Importance of the nature and properties of bottom soils of brackishwater fish ponds has also been emphasized by workers like Tang and Chen (1967), Djajadiredja and Poernomo (1972) and others.

Because of the important role of the brackishwater pond soils in fish production, it was considered worthwhile to make a detailed study of the physico-chemical properties of the soils of some of the brackishwater fish ponds in West Bengal, a leading fish culturing state in India, with a view to assess their production potentiality as well as to identify the soil factors responsible for poor production.

MATERIAL AND METHODS

Representative soil samples collected from sixteen different ponds, covering the main brackishwater fish farming areas of West Bengal, were air dried, ground and passed initially through a 2 mm and then through a 80 mesh sieve to prepare the samples ready for subsequent analyses. Organic carbon content of the soils was determined by the wet digestion method of Walkley and Black (1934) using silver sulphate to overcome the interference of Cl ions. Free $CaCO_3$ content of the soils

* This work formed a part of Ph.D. thesis by the senior author.

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was determined according to the method described by Piper (1966). International pipette method (Piper, 1966) was followed for mechanical analysis of the soils. Determinations of pH, E.C., water soluble cations and water soluble anions were carried out using 1 : 2.5 soil : water ratio. Among water soluble cations, Ca and Mg were determined by versenate titration and Na and K by the help of a flame photometer. Among water soluble anions, Cl, SO_4, CO_3 and HCO_3 were estimated by following the methods described by Jackson (1967). Amounts of exchangeable Ca, Mg, Na and K in the soils were determined by extracting the soils with neutral (N) Ammonium acetate solution after removing the water soluble salts by washing with distilled water followed by 40% alcohol (Piper, 1966).

Results and Discussion

The results of the mechanical analysis of the soils show that texturally they belong mostly to silty clay loam group, followed by silty loam, silty and clay loam respectively (Table 1 A). The importance of soil texture on the productivity of brackishwater fish ponds has been emphasized by Djajadiredja and Poernomo (1972). Besides the organic carbon and nutrient content of the soils, many other important physico-chemical properties having relation with productivity of ponds are determined to a great extent by the relative proportion of the different size fractions of the soil particles. Tang and Chen (1967) surveyed some milk fish ponds in Taiwan and described that majority of the highly productive ponds were distributed in the regions having silty loam soils. The textuarl composition to the soils therefore, indicate that the brackishwater fish ponds of West Bengal are likely to have fairly good productive potentiality.

Organic carbon content of the pond soils ranged from 0.24 to 0.59 per cent with an average value of 0.41 per cent (Table 1 A). Similar was the observation of Gopalaswamy and Raychaudhuri (1970), who, while working on some saline marshy soils of West Bengal, proximating to sea, reported the soils to be low in organic matter. Tang and Chen (1967) emphasized the importance of soil organic matter in the productivity of brackishwater ponds and demonstrated that the annual yield of such ponds increased with increase in organic carbon content of the soil. Banerjea (1967) rated the productivity of freshwater fish ponds on the basis of the organic carbon content of the bottom soils and considered values below 0.5 per cent as too poor for fish production. In the present study it was observed that out of sixteen soils only two contained organic carbon slightly above 0.5 per cent. On the basis of the criterion suggested by Banerjea (1967), the organic carbon content of bottom soils of the brackishwater ponds of West Bengal may be considered to be too poor to give a satisfactory production and hence application of organic manures may be useful for improving the productivity of these ponds.

pH values of the soils ranged from 7.90 to 8.40) with an average value of 8.19 (Table 1 A). Since the soils of these ponds remain waterlogged with highly saline tidal water, such high pH values are not unlikely and a highly significant statistical correlation was found to exist between pH and E. C. values of the soils (Table 2). The pH values were, in contrary to common observations, found to be negatively correlated with free $CaCO_3$ content of the soils, which may be explained by assuming that the free $CaCO_3$ have lowered the relative proportion of Na and increased that of Ca in the soil exchange complex and in the solution phase. Importance of neutral to slightly alkaline pH values of pond soils and water on fish production has been emphasized by workers like Ohle (1938), Neess (1949) and many others and accordingly the slightly alkaline pH values of the soils of brackish-

TABLE 1 A. *Physico-chemical properties of the brackishwater fish pond soils of West Bengal*

Location		pH	O.C. (%)	E.C. (mmhos/cm)	$CaCO_3$ (%)	Sand (%)	Silt (%)	Clay (%)
Bagdanga	..	8.30	0.46	8.30	1.87	37.50	41.30	21.20
Kusumtala	..	8.35	0.59	8.30	4.00	30.00	41.30	28.70
Baliara	..	8.35	0.44	8.30	3.50	20.00	62.50	17.50
Debnagar	..	8.40	0.31	7.10	4.00	35.00	35.00	30.00
Kastala	..	8.25	0.39	8.30	3.87	47.60	18.70	33.70
Suryapur	..	8.40	0.40	8.00	3.50	51.30	32.50	16.20
Seikherlat	..	8.25	0.39	8.00	4.10	45.00	30.00	25.00
Halderlat	..	8.35	0.42	7.40	2.50	45.00	45.00	10.00
Bibirgheri	..	8.00	0.45	3.20	7.00	28.80	42.50	28.70
Purbadwipmede	..	7.90	0.47	3.00	8.20	27.30	32.50	26.20
Paschimdwipmede	..	7.95	0.55	4.20	8.00	17.50	47.50	35.00
Sagar	..	8.30	0.25	8.00	5.70	27.50	40.00	32.50
Mandirtala	..	8.35	0.24	8.30	4.50	23.80	51.20	25.00
Nischintapur	..	8.10	0.42	3.50	3.00	20.00	55.00	25.00
Kakdwip	..	8.00	0.47	7.90	3.75	27.50	42.50	30.00
Diamond Harbour	..	7.90	0.36	3.80	3.30	26.30	38.70	35.00
Average	..	8.19	0.41	6.60	4.42	31.30	41.60	26.20

water ponds of West Bengal may be considered to be conducive for higher production.

Free $CaCO_3$ content of the soils varied from 1.87 to 8.20 per cent with an average of 4.42 per cent. As has been discussed earlier, comparatively larger amounts of $CaCO_3$ were observed under the regions having comparatively lower pH values and vice-versa. Apart from nutritional values, importance of free $CaCO_3$ in neutralising the organic and inorganic acids resulting from anaerobic decomposition of organic matters under submerged condition has been described by Wunder (1949). Hence the fairly high values of free $CaCO_3$ content of the soils is likely to be useful in counteracting some possible harmful effects of organic manuring, which has been suggested in view of the low organic carbon content of the brackishwater pond soils of West Bengal.

The E. C. values of the pond soils were in the range of 3.0 to 8.3 mmhos/cm with an average value of 6.6, most of the soils recording values near about 8.0 mmhos/cm. The values, in general, decreased as the distance of the location of the ponds from the main estuary increased. Subramanyan *et al.* (1976), also found that the severity of salinisation of both soil and water in some coastal areas of West Bengal increased with decreasing distance from the river systems and the sea coast. High E. C. values were due to presence of large amount of water soluble cations and anions in such soils which is evidenced from the highly significant statistical correlations between them (Table 2). The variation of E.C. of the pond soils may be associated with a variation in the relative distribution of different cations and anions in the pond water which might cause a change in the composition as well as the growth of the fish food organisms and thus the productivity of the ponds.

Total water soluble cation content of the soils ranged from 7.0 to 34.8 me/100 g soil with an average value of 16.1 (Table 1 B). Out of different cations, Mg was present in

TABLE 1 B. *Physico-chemical properties of the brackishwater fish pond soils of West Bengal*

Location	Water soluble cations				Water soluble anions				Exchangeable bases			
	Ca	Mg	Na	K	Cl	SO_4	CO_3	HCO_3	Ca	Mg	Na	K
						(me/100g soil)						
Bagdanga ..	8.50	22.50	3.40	0.40	33.50	4.20	0.05	0.21	13.60	25.60	2.50	5.90
Kusumtala ..	5.30	11.70	2.90	0.30	20.80	4.10	—	0.19	15.20	12.80	2.10	5.60
Baliara ..	4.00	12.70	2.30	0.30	20.60	3.10	—	0.20	19.20	16.00	2.50	6.60
Debnagar ..	2.40	4.30	0.90	0.20	6.30	1.90	0.05	0.43	19.20	16.80	2.10	7.70
Kastala ..	5.80	13.90	2.20	0.30	20.90	4.30	0.02	0.26	12.80	13.60	2.50	7.20
Suryapur ..	6.40	10.30	1.10	0.40	18.90	2.50	—	0.15	11.20	8.80	0.80	3.30
Seikherlat ..	6.30	11.30	1.10	0.40	18.30	2.60	0.01	0.30	13.60	13.60	1.20	3.90
Halderlat ..	5.00	7.20	1.30	0.30	12.70	2.70	—	0.29	10.40	12.80	1.20	5.40
Bibirgheri ..	2.50	4.50	1.10	0.20	8.90	1.50	0.04	0.43	20.00	13.60	1.30	4.30
Purbadwipmede ..	3.10	6.40	0.90	0.10	9.10	1.40	0.02	0.33	20.80	10.40	0.80	2.60
Paschimdwipmede ..	6.80	7.80	1.30	0.20	14.10	1.70	0.18	0.53	24.80	14.40	1.20	4.90
Sagar ..	3.30	8.80	2.40	0.30	17.50	0.70	0.04	0.27	11.20	15.20	2.20	7.50
Mandirtala ..	5.80	12.30	3.10	0.40	22.20	2.10	0.02	0.23	11.20	13.60	2.10	8.20
Nischintapur ..	1.90	3.30	1.70	0.10	8.90	1.60	0.03	0.33	14.40	16.00	1.30	5.80
Kakdwip ..	3.80	3.80	1.90	0.20	11.30	1.40	0.02	0.26	11.80	10.40	1.70	5.40
Diamond Harbour ..	2.00	4.50	1.30	0.10	6.10	1.80	0.08	0.32	13.60	16.00	1.90	6.70
Average ..	4.50	9.40	1.90	0.30	15.60	2.30	0.03	0.29	15.20	14.30	1.70	5.40

the highest amount ranging from 3.3 to 22.5 with an average value of 9.4 me/100 g soil, followed by Ca, ranging from 1.9 to 8.5 with an average value of 4.5 me/100 g soil and Na ranging from 0.9 to 3.4 with an average value of 1.9 me/100 g soil. K was present in the least amount, ranging from 0.1 to 0.4 me/100 g soil. Dominance of Mg over Ca in sea water (Harvey, 1960) and consequently in the estuarine water, which serves the source of water in brackishwater fish ponds, might be the reason for the dominance of Mg ions in these soils. Amount of water soluble Na in the pond soils increased with increase in E. C. values and decrease in the distance from the main estuary. Presence of comparatively higher amount of water soluble Ca and Mg over that of Na in the soils may be considered to be beneficial for brackishwater ponds not only because these two constitute important nutrient elements for the fish food organisms but also help to minimise some of the adverse effects of excess Na ions on the physico-chemical properties of the soils. It is interesting to note that K, although present in the least amount in water soluble form, was present in the soil exchange phase in amounts greater than that of Na. These observations are in agreement with those of Goldschmidt (1934) who explained presence of comparatively smaller amounts of K in sea water as due to its more ready absorption on particles of detritus and its consequent accumulation in bottom deposits.

Total amount of water soluble anions (Cl, SO_4, CO_3, HCO_3) ranged from 8.30 to 37.90 with an average value of 18.30 me/100 g soil (Table 1 B). Cl was the most dominant anion ranging from 6.10 to 33.50 me/100 g soil, followed by SO_4 ranging from 0.70 to 4.30 me. HCO_3 was present in rather low quantities ranging from 0.15 to 0.53 me/100 g soil and the amount of CO_3 was very small in most of the soils and even totally absent in 25 per cent of the number of soils studied. The results are in agreement with those of Gopalaswamy and Raychaudhuri (1970), who reported Cl followed by SO_4 to be the most dominant anions for coastal saline marshy soils of West Bengal.

Total amount of exchangeable bases in the soils was quite high, which ranged from 24.1 to 47.6 with an average value of 36.7 me/100 g soil (Table 1 B). The results are in agreement with those of Gopalaswamy and Raychaudhuri (1970), who also reported high base exchange capacities (19-36 me) for similar coastal marshy soils. Presence of such large amount of exchangeable cations in the bottom soils, in spite of their low organic carbon content might be due to the occurrence of finer sized particles in relatively higher proportions in the soils. But since no such statistical correlation could be obtained between the content of exchangeable bases and the amount of different size fractions, the nature of clay minerals, which has been described to be of 2 : 1 type for similar alluvial soils by Mukherjee *et al.* (1971) appears to be the main factor for the presence of high amount of exchangeable cations in such soils. Among the exchangeable bases, Ca and Mg were

TABLE 2. *Statistical correlation between different properties of brackishwater fish pond soils*

Properties	'r' *values*
Clay vs Exch. bases ..	0.268
pH vs E.C. ..	0.813**
pH vs $CaCO_3$ ..	−0.530*
pH vs Exch. Na ..	0.389
pH vs Exch. bases ..	0.084
E. C. vs water soluble cations ..	0.680**
E. C. vs water soluble anions ..	0.690**
Silt + Clay vs Exch. bases ..	0.097
Water soluble cations vs anions ..	0.979**
Exchangeable Na vs water soluble Na ..	0.783**
Exchangeable cations vs water soluble Na ..	0.402

** Significant at 1% level

* Significant at 5% level

present in almost equal amount followed by K and Na with respective average values of 15.2, 14.3, 5.4 and 1.7 me/100 g soil. Presence of higher amount of water soluble Ca and Mg in the soils can explain the dominance of the Ca and Mg ions in the soil exchange phase. Occurrence of higher amount of K over Na in the soil exchange phase in spite of higher concentration of Na in water soluble form may be due to the fact that K is adsorbed more readily than Na by the soil colloids (Paliwal, 1972). This may be considered beneficial for brackishwater aquaculture since Pillay *et al.* (1962) observed productivity of brackishwater ponds to depend largely on this form of K. Amount of exchangeable Na, however, increased with the increase in the amount of water soluble Na and highly significant statistical correlation was observed between the contents of Na in these two forms (Table 2).

The present study showed that the soils of brackishwater fish ponds of West Bengal have favourable physico-chemical properties for productivity, but contain low amount of organic carbon which may act as production constraint in these ponds.

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PROSPECTS OF AQUACULTURE IN A MANGROVE ECOSYSTEM

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ABSTRACT

The mangrove ecosystem at Pichavaram, near Parangipettai, Tamil Nadu is one of the best coastal zone ecosystems for aquaculture practices. The procurement of wild variety seeds from these typical nursery grounds are of economic importance. The diverse niches existing in the mangrove ecosystem provide opportunities for herbivorous, carnivorous and omnivorous types of fish culture. The naturally endowed nutrients and the abundant detritus pave way to a flourishing food web and thus to a unique and surplus potential of amenable aquaculture species. The detritus feeders promise more yield, among the trophic tiers of organisms of the mangroves.

About 30 species of ichthyofauna and 20 species of shellfishes amenable for aquaculture are available from these mangroves. The appropriate seasons for collecting these wild fry resources for aquaculture practices are listed. The seasonal availability of adult fishes with ripe gonads for breeding in captivity is given. Certain species with appreciable growth rate observed in these natural waters are recommended for aquaculture. Organisms fit for polyculture in these environs are discussed.

Problems related to environmental variables such as salinity, temperature, dissolved oxygen, tides, monsoonal precipitation and drainage are discussed. Biotic problems such as seed resources, recruitment failure, menace by predators, threat posed to mangrove vegetation through siltation by farm construction and deforestation are discussed. Aquaculture in mangroves can be used for replacing illicit fishing of under sized fishery resources.

INTRODUCTION

MANGROVE ecosystem is one of the most productive coastal zone ecosystems. The producers are of diverse variety and they include photosynthetic bacteria, phytoplankton, benthic diatoms, floating epiphytic and benthic algae, submerged marine angiosperms and halophytic marshy vegetation besides typical mangrove vegetation. The energy input from mangrove vegetation to the water channels promotes the fertility of soil and water. The mangrove ecosystem possesses potential sites for aquaculture practices. The mangrove water ways support fishery constituted by certain brackishwater fishes. The mangroves also serve as nursery ground for many marine fishes. Surplus seed resources are available from this productive ecosystem for aquaculture practices. Fry of restricted brackishwater fish species are available in enormous quantity, whereas many marine fish 'seeds' are available fair in numbers for culture practices. Few culturable freshwater fish species are also available from these mangroves. 'Seeds of shellfish resources are of much importance from culture point of view. There are a good number of aquatic plants and animals available in the mangroves, which can be used as live food for cultivable organisms. Artificial food can be prepared from leaves of mangrove vegetation, which can be used for culture practices. The detritus derived from degradation of mangrove litter and the colonizing groups including bacteria, fungi, ciliates and nematodes form food for certain culturable organisms. Few species of aquatic organisms are available with ripe gonads in the mangroves, which can be used for breeding in captivity, induced breeding and for ranching the sea with selective species. The physico-chemical properties of water and sediments from the mangrove ecosystem are suitable for aquaculture. The water resources of the culture tanks can either be filled or be drained by proper construction coinciding with the tidal influence. This paper deals the aquaculture prospects with merits and demerits from point of view of a South Indian mangrove ecosystem ' Pichavaram ' with an area of about 15 sq. km and is influenced by neritic, brackish-water and freshwater influx near Porto Novo (11°29′ N; 70°49′E) in Bay of Bengal sea board of Southeast Indian Coast.

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Material and Methods

Intensive faunal and floral collections were made from the Pichavaram mangrove ecosystem on a year round basis. Fortnightly collections were made for assessing physico-chemical parameters (including salinity, temperature, dissolved oxygen, hydrogen ion concentration, light extinction coefficient and seston) and biological parameters (including phytoplankton, epiphytic diatoms, benthic algae, marine angiosperms, zooplankton and benthic fauna). Finfish and shellfish were collected by experimental gears, as well as from local fishing centres. The species and size ranges were recorded season wise. The food of finfishes were analysed and their maturity stages noted. The quantity of fish and shellfish exploitation by local gears, the species composition and their size composition were assessed. The results are presented seasonwise for convenience. The four seasons which can be recognized in the area are :

NE monsoon season (October to December),
Postmonsoon season (January to March),
Summer season (April to June) and
Premonsoon season (July to September).

Results and Discussion

Mangrove Potential

Major culturable seeds available in Pichavaram mangroves in the order of abundance are prawns, fishes, clams, oysters, crabs, cockles and mussels. So far 147 species of finfishes belonging to 102 genera and 56 families have been recorded from this mangrove ecosystem. They may be grouped as follows : 74 species are marine forms, 64 species are brackish-water components and the rest are freshwater species. Of these, representatives of 18 families belonging to 26 genera and 34 species are important from finfish culture point of view. They include 11 species of marine components, 16 species of brackishwater forms and 7 freshwater species. This mangrove ecosystem supports about 50 species of shellfish resources, of which prawns and shrimps constitute 23 species. Of the shellfish resources about 20 species are cultivable.

Finfish resources

Elopidae

The leptocephalus like postlarva of the ten pounder *Elops machnata* (Forsskal) occurs round the year in the mangroves except during certain days of monsoon and postmonsoon season, with peak occurrence during late summer. Fry of this fish occur abundantly during early premonsoon and fingerlings during late monsoon. This fish is a carnivore feeding on prawns and fishes. Though the fry resources are surfeit in the mangroves, the flesh quality is of low market value hence of little importance from aquaculture point of view. It is an aggressive predator causing menace by entry into prawn culture ponds here.

Chanidae

The larval abundance of the milkfish *Chanos chanos* Forsskal in the mangrove ecosystem can be recognized during summer and monsoon. Fry and fingerlings were available during late summer and early premonsoon seasons in the mangrove channels. Adults are never encountered in the shallow channels of the mangrove ecosystem. Fingerlings with stunted growth can also be collected during late postmonsoon season from shallow water pools, which once confluenced with the main channels during spring high tides. They would remain cut off during neap tides. This fish is an omnivore feeding on detritus and algal bed in the mangroves.

Bagridae

Among bagrid catfishes *Macrones gulio* (Hamilton) and *M. vittatus* (Bloch) occur in the mangroves. The former is dominant. It occurs only as juveniles in the mangroves and the seeds occur in enormous numbers in the upper reaches of the mangroves, around the sewage polluted area, almost throughout the year. *M. gulio* can also cope up with a wide range of salinity fluctuation and it is occurring even at the salinity of 30‰ in natural waters. It shows strict zonal distribution, occurring only in the upper reaches of the mangroves. Rarely, adults of *M. vittatus* with ripe gonads occur in the mangroves during the monsoon season. These bagrid catfishes are omnivores and scavengers. Their market value is less and of lesser importance from aquaculture point of view. However, they may be useful for sewage-fed fish culture practices.

Cyprinodontidae

Two species of 'top minnows' occur in the mangrove waterways and they are *Panchax melastigma* Mc Clelland and *Panchax panchax* (Hamilton), the former is dominant in the mangroves. *Panchax melastigma* is occurring throughout the year, whereas *Panchax panchax* is occurring seasonally only during (the period of freshwater drainage) monsoon season. *P. melastigma* is also occurring in higher saline waters of the mangroves (upto 30‰) and adults with attached eggs (brood) can be collected from the area. This fish species can be collected in large quantities from the sheltered pools adjacent to mangrove channels, as well as around the proproots of the mangrove trees *Rhizophora mucronata* Lamk. and *R. apiculata* Bl. where the tidal current is feeble. The mosquitoes breed in the intertidal belts of the mangroves and the larvae are fed by these fishes.

Mugilidae

Among mullets seeds of *Mugil cephalus* Linnaeus, *Liza dussumieri* (Valenciennes), *L. macrolepis* (Smith), *L. parsia* (Hamilton), *Osteomugil cunnesius* (Valenciennes) and *O. speigleri* (Bleeker) are found in good numbers. *Mugil cephalus, Liza dussumieri, L. macrolepis* and *L. parsia* are primarily detritus feeders, whereas *Osteomugil cunnesius* and *O. speigleri* show preference to algal matter.

Fry of *Mugil cephalus* is available during late monsoon and postmonsoon seasons whereas adults of this species with ripe gonads are available scarcely during monsoon season. Fry of *Liza dussumieri, L. macrolepis* and *L. parsia* are occurring abundantly during late monsoon and postmonsoon seasons, whereas the fingerlings of these species occur abundantly during summer. However, these species show year to year fluctuation in fry occurrence and abundance. The good sites for collecting the mullet fry are narrow creeks of the mangroves. These fry ascend up the narrow creeks along with the tidal flow and descend down with tidal ebb. However, during summer, when the neritic water occasionally doesn't flow into the creeks isolated small schooling patches can be occasionally spotted nearby the shore regions of main channels.

Adults of the above three *Liza* spp. with ripe gonads sporadically occur during monsoon and post-monsoon seasons in the mangroves. Adults of *Liza parsia* with ripe gonads are comparatively frequent than the other two *Liza* species.

Fingerlings of *Osteomugil cunnesius* occur during postmonsoon and early summer. Juveniles of *O. cunnesius* and *O. speigleri* occur abundantly during early summer. However, they show year to year fluctuation. Other members of the family Mugilidae namely *Liza tade* (Forsskal), *Ellocheon vaigaiensis* (Quoy and Gaimard) and *Rajamugil oligolepis* (Bleeker) occur in the Pichavaram mangroves scarcely and hence of little importance from aquaculture point of view. Besides, *Rajamugil oligolepis* grows only to a little size (10 cm length).

Centropomidae

The cock-up *Lates calcarifer* (Bloch) is a carnivorous fish commonly used for brackish-water fish culture. The seeds are available in the mangroves during late summer, premonsoon, early monsoon and early postmonsoon with a peak period of abundance during late premonsoon. The adults form winter fishery during monsoon months. This fish is also causing problem to culture of other fishes and prawns due to its predacious behaviour.

Cichlidae

Among cichlids, *Etroplus suratensis* (Bloch), *Etroplus maculatus* (Bloch) and *Tilapia mossambica* Peters are the species represented in this mangrove ecosystem, of which *E. suratensis* is dominant. Fry of *E. suratensis* are available during premonsoon, monsoon and postmonsoon with peak abundance during late premonsoon and early postmonsoon. *E. maculatus* and *Tilapia mossambica* occur only in upper reaches of the mangroves, where limnetic and oligohaline condition prevail. They do not occur in considerable quantity. *Etroplus suratensis* is suitable for brackish-water fish culture whereas *E. maculatus* and *Tilapia mossambica* are suitable for freshwater fish culture.

Siganidae

Two species of rabbitfishes occur in the Pichavaram mangroves and they are *Siganus javus* (Linnaeus) and *S. canaliculatus* (Park). Of these two species, *S. javus* is dominant and *S. canaliculatus* sporadically occurs. Fry of *S. javus* is available during early premonsoon and in certain years they are also available during summer and premonsoon. Fry of this species shows year to year fluctuation in occurrence. This species shows niche specificity, occurring predominantly in algal beds, especially in lower reaches of the mangroves. In nature, seeds of *S. canaliculatus* occur in poor numbers. Both *S. javus* and *S. canaliculatus* are amenable species for marine fish culture, but may not be suitable for culture in turbid waters.

Miscellaneous finfishes

Juveniles and adults of the Indian tarpon *Megalops cyprinoides* (Broussonet) rarely occur in upper reaches of the mangroves during monsoon season coinciding with the freshwater influx in the area. The eels *Anguilla bicolor* Mc Clelland and *A. bengalensis* (Gray and Hardwicke) occur in the burrows of upper reaches of the mangroves. They are also occasionally caught by local fishermen when they dig the burrows for extricating principally the mangrove crab *Scylla serrata* (Forsskal). The climbing perch *Anabas testudineus* (Bloch) occurs in considerable numbers in upper reaches of the mangroves, where salinity of the water is almost nil and the soil is clayey mud. This fish is good for culture in marshy areas of the mangroves. The snakehead *Channa striatus* (Bloch) which occurs in the upper reaches of the mangroves is allochthonous and the juveniles of this species drift in the flood season. The seeds of this species can be collected for freshwater aquaculture, immediately after flood from the adjacent shallow water pools and also from the zones of a halophytic vegetation *Acanthus ilicifolius* L. near upper reaches of the mangroves, where the water is almost fresh. Other fishes that rarely drift to the mangroves during flood season are *Labeo rohita* (Hamilton) and *Puntius chola* (Hamilton).

Among 19 species of gobioids available from the mangroves, *Glossogobius giuris* (Hamilton) is the only species amenable for culture. This fish is primarily a freshwater form. The fingerlings of this species occur even in waters with the salinity of 32‰. This species also spawns in the mangroves during flood season upon hardened substrata or sediment. Fry is occurring in small numbers during premonsoon and early monsoon seasons. This species is fit for freshwater aquaculture. However, juveniles of this species are euryhaline forms.

Among the family Sparidae, the gold lined sea bream *Rhabdosargus sarba* (Forsskal) and the picnic sea bream *Mylio berda* (Forsskal) occur in the mangroves, of which *R. sarba* is suitable for aquaculture. Since the frequency of occurrence of its seed is poor in mangroves it is of little importance in the present study area.

Shellfish resources

Eleven species of penaeid prawns and twelve species of non-penaeid prawns occur in the mangrove ecosystem. Of these, six species of penaeids and four species of non-penaeids can be considered for aquaculture. The culturable penaeid prawns are *Penaeus indicus* Milne-Edwards, *P. monodon* Fabricius, *P. merguiensis* de Man, *P. semisulcatus* de Haan., *Metapenaeus dobsoni* Miers and *M. monoceros* (Fabricius). The culturable non-penaeid prawns are *Macrobrachium idae* Heller, *M. malcolmsoni* Milne-Edwards, *M. scabriculum* (Heller) and *M. rosenbergi* (de Man). Of the above penaeid prawns, seeds of *P. indicus*, *M. monoceros* and M. *dobsoni* occur in large quantities and can be utilized for prawn culture. The larvae and juveniles of these prawns use mangroves as nursery ground. They can be harnessed as a good source of seed for aquaculture.

Seeds of *Penaeus indicus* occur throughout the year with abundance during postmonsoon and summer. Seeds of *Penaeus monodon* occur throughout the year with greater intensity during monsoon season. Seeds of *Penaeus semisulcatus* occur throughout the year except during monsoon season in the mangroves, with peak period of abundance during premonsoon. Juveniles of this species show niche specificity, occurring only in the algal beds in lower reaches of the mangroves, where the water is less turbid. Seeds of *Metapenaeus dobsoni* and *M. monoceros* occur throughout the year with surplus availability during monsoon and postmonsoon seasons.

Among non-penaeid prawns, *Macrobrachium idae*, *M. malcolmsoni*, *M. scabriculum* and *M. rosenbergi* occur only in the monsoon season. Among these four species, *M. idae* forms fishery during monsoon season. *M. malcolmsoni* scarcely occurs whereas, *M. rosenbergi* and *M. scabriculum* are rare in the mangroves. Berried females and mature males of *Macrobrachium idae* and *M. malcolmsoni* are available in the mangroves during the monsoon season, among them the former one is dominant.

Seeds of the mangrove crab *Scylla serrata* (Forsskal) are available in small amount during monsoon and postmonsoon seasons. Juveniles of *Portunus pelagicus* (Linnaeus) and *P. sanguinolentus* (Herbert) occur in the mangroves, of which the former occurs in fair numbers and the later less frequently. Both these *Portunus* spp. are usually restricted to lower reaches of the mangroves whereas *Scylla serrata* shows wide range of distribution within the mangroves.

Seeds of the clams *Meretrix meretrix* (Linnaeus), *M. casta* Deshayes and *Katelysia opima* (Gmelin) are abundant during summer season in the mangrove ecosystem. The seed as well as the adult clam resources are utilized exclusively for lime industry in this area. Proper utilization of these resources may help to solve the problem of protein deficiency. The oyster *Crassostrea madrasensis* (Preston) and the cockle *Anadara rhombea* (Born) though available in considerable quantities, are not properly utilized for human consumption. Before attempting to culture these organisms, steps should be taken for proper marketing and utilization of available natural resources from this area. The backwaters adjacent to mangroves may be utilized for culturing these clams, cockles and oysters. The green mussel *Perna viridis* (Linnaeus) is posed with the problem of survival due to siltation and decline in salinity caused by monsoonal flood.

REMARKS

Plotosus canius Hamilton is a marine catfish eel with appreciable growth rate in natural waters. This fish is an omnivore feeding on benthic organisms and decaying organic matter. It is also an euryhaline and turbidity tolerant species. The seeds occur in considerable numbers in lower reaches of the mangroves, especially adjacent to mud flats of oyster bed regions. It is a venomous fish and care should be taken during handling processes. *Epinephelus tauvina* (Forsskal) and *Lutjanus johni* Bloch are carnivores with appreciable growth rate. The seed are also considerable in the mangroves. Culture of these fishes in cages with trash fish feed may prove profitable. *Scatophagus argus* (Linnaeus), a principally herbivore, can also be cultured in special tanks by providing naturally occurring algal weeds such as *Enteromorpha* spp., *Chaetomorpha* spp., *Cladophora* sp., *Gracilaria* spp. and *Hypnea* sp., *S. argus* is reported to be a milkfish competitor. Other coexisting organisms such as *Etroplus suratensis*, *Siganus javus*, *S. canaliculatus* and *P. semisulcatus* may be fit for polyculture practices among herbivores.

The mudskipper *Boleophthalmus boddarti* (Pallas) is occurring in considerable measure from the intertidal regions of the mangrove ecosystem. At present the natural stocks are not harvested or utilized. *Boleophthalmus* sp. is cultured in Taiwan for its delicacy. However, it is not relished by local people. Similarly, pufferfishes are totally rejected by Indians, whereas Japanese are culturing these fishes for fulfilling their protein needs. Proper culturing of these pufferfishes may boost export. It will solve to some extent the problem of protein deficiency. Seeds of four species of pufferfishes occurring in the mangroves are *Arothron reticularis* (Bloch), *Chelanodon patoca* (Hamilton), *Gastrophysus lunaris* (Bloch) and *Tetrodon fluviatilis* Hamilton of which the last one is of potential importance. Both the mud skippers and pufferfishes are of promise for future aquaculture exploitation.

POLYCULTURE SPECIES

The following combination of cultivable organisms may be suitable for polyculture practices based on the feeding types, coexistence, turbidity tolerance, tolerance to salinity fluctuations and seasonal availability of seeds in the Pichavaram mangrove ecosystem.

1. *Mugil cephalus* + *Liza macrolepis* + *L. dussumieri* + *L. parsia* (detritus type of feeding and early postmonsoon stocking).
2. *Chanos chanos* + *Liza macrolepis* + *L. dussumieri* + *Penaeus indicus* (Detritus type of feeding and early summer stocking).
3. *Penaeus indicus* + *P. monodon* + *Metapenaeus dobsoni* (detritus type of feeding and monsoon stocking).

4. *Siganus javus* + *S. canaliculatus* + *Etroplus suratensis* + *Scatophagus argus* + *Penaeus semisulcatus* + *Osteomugil cunnesius* (herbivorous feeding type and premonsoon stocking).

5. *Lates calcarifer* + *Epinephelus tauvina* + *Lutjanus johni* + *Scylla serrata* + *Etroplus suratensis* + *Metapenaeus monoceros* + *Gobioids* + *Leiognathids* (Predators with prey organisms supplemented with trash fish).

Physico-Chemical Parameters of the Mangrove Ecosystem and its suitability for Aquacultulre

The depth of the channels within Pichavaram mangrove ecosystem varies from 0.5 to 1.8 m, with an average of 1 m. The tidal amplitude varies from 0.3 to 0.9 m. The lower level of tidal amplitude is prevailing during summer and the higher level during winter. Draining and filling up of water in culture tanks through sluices, based on tidal ebb and flow may not be effective during summer, so resort to pumping arrangement if necessary.

The back mangroves with salt flats and interior mangroves with mud flats may be useful for constructing culture ponds.

During cyclonic weather, the water level in the mangroves increases to 2 m more beyond normal level owing to tidal inflow. The successive freshwater flood draining through this deltaic area immediately after cyclone also contributes to the increase in the water level. Clayey soil available in the mangrove area may be suitable for bund construction to cope up the high velocity of water flow during cyclonic period to prevent erosion.

The mangrove soil is very productive. Regional and seasonal variation in clay, silt and sand composition of soil is evident within the mangrove ecosystem. The ratio of clay, silt and sand in the mangrove sediments of channels is 2 : 1 : 2 and that of the *Avicennia* zone is 6 : 1 : 1. Silt composition in surface soils of mangrove channels is dominant during monsoon and early postmonsoon, whereas sand composition is always dominant in lower reaches of the mangroves. Organic matter in the soil varies from 1 to 14% ; the higher content in soils comprises mostly clay and silt. However, the average organic content value is less when compared to certain Indo-Pacific mangroves. Detritus feeding organisms are more suitable for aquaculture in this mangrove ecosystem. The pH of soil in water channel is always alkaline ranging from 7.1 to 8.2, excepting during monsoon season when the soil is slightly acidic. The soil of back mangrove is slightly acidic, with pH ranging from 6.5 to 7, especially of those stations near *Avicennia marina* where accumulation of litter and higher concentration of humic substances prevail. The buffering effect of sea water is not much evident in this back mangrove area ; hence the acidic pH. Total phosphorus of mangrove soil is reported to range from 0.03 to 0.07% and total nitrogen from 0.05 to 0.12% (Dhevendaran, 1977).

Salinity of the water ranges from almost nil to 33‰ in this mangrove ecosystem. Freshwater dominates during most of the monsoonal months if the north east monsoon outbreak is a success. The salinity is also at times very low and even freshwater condition prevails in the mangroves for shorter periods during postmonsoon and summer, due to release of surplus water from the storage reservoirs of the nearby catchment areas. The drop of salinity and return to freshwater condition in this monsoon influenced area during the rainy season poses problem for culturing stenohaline organisms. The organisms with extreme plasticity to salinity changes (mixohaline forms) may be cultured in this area. However, short term culture practice of fast growing organisms which may not be tolerable to oligohaline condition (0.5—5.0‰) may be cultured in this mangrove ecosystem during non-monsoon seasons, preferably by stocking around January and harvesting within nine months period, before the on set of north east monsoon during October-November. Organisms tolerable to polyhaline condition (18-30‰ salinity) may be restricted to culture in lower reaches of the mangroves. However, knowledge about growth of the fish in varying salinity is a prerequisite before selecting organisms for aquaculture, besides mere salinity tolerance.

The surface temperature in natural waterbodies of mangroves range from 22 to 34°C. The hydrogen ion concentration of water is ranging from 7.1 to 8.5 and is optimum for fish culture. Dissolved oxygen concentration in the water is ranging from 3.0 ml to 7.6 ml/1 with the mean value of 4.8 ml/1 which is optimum level for culture practices. The nutrient levels in water bodies of mangrove ecosystem are as follows: The total phosphorus ranges from 0.35 to 2.19 μg at/1 ; inorganic phosphate from 0.18 to 1.32 μg at/1 ; nitrate from 0.48 to 10.0 μg at/1 ; nitrite from 0.05 to 0.50 μg at/1 and silicate from 26.8 to 170.0 μg at/1 (Krishnamurthy *et al.*, 1975 ; Sundararaj, 1978).

Biological Parameters of Mangrove Ecosystem and Its Suitability for Aquaculture

Live food resources both plants and animals are plenty and ideal for aquaculture in this mangrove ecosystem. The productivity of the Pichavaram mangrove ecosystem is also very high, with the gross production ranging from 117.6 to 836.9 mg C/m^3/hr and net production from 42.0 to 588.2 mg C/m^3/hr. The maximum chlorophyll *a*, *b* and *c* values recorded from this mangrove ecosystem are 32.4, 14.1 and 59.2 mg/m^3 respectively. The maximum values values of bacterio-chlorophyll *a*, *c* and *d* recorded are 54.5, 36.0 and 32.0 mg/m^3 respectively. The plankton volume ranges from 0.07 to 8.7 cc/m^3 (Krishnamurthy *et al.*, 1975 ; Panneerselvam *et al.*, 1979 ; Sundararaj, 1978).

In the waterways of Pichavaram mangroves, the nannophytoplankton biomass ranges from 3×10^4 to 26.56×10^7 cells/m^3, netphytoplankton from 500 to 77,50,000/cells/m^3, microzooplankton from 24,000 to 46,00,000 organisms/m^3, mesozooplankton from 2,800 to 13,50,000 organisms m^3 and macrozooplankton varied upto 2,950 organisms/m^3. All these richly endowed biological characteristics bear eloquent testimony for the suitability of this ecosystem for aquaculture.

Problems of Aquaculture in the Mangrove Ecosystem

The failure in seasonal rainfall in certain years poses problem in procuring certain types of seeds. Certain fishes also pose problems regarding their availability due to their stenohaline nature or sensitivity to even slight salinity alteration, caused by irregular influx of freshwater from drainage channels into the mangrove ecosystem.

The upper reaches of the mangroves are subjected to threat by the presence of pesticide pollutants transported through agricultural drainage. This problem is prevalent for a short duration during premonsoon season. It starts within a month from the date of release of water from the Veeranam tank. The larvae, postlarvae and juveniles affected in the short duration and the persistence of those residues in aquatic organisms and their long term effects affect the environmental quality.

Building culture tanks by blocking the waterways may alter the tidal current pattern and may cause siltation, leading to poor productivity of the soil and water, by affecting the growth of mangrove vegetation. Certain vast shallow embankments in the lower reaches of the mangrove ecosystem support luxuriant growth of algal weeds (such as *Enteromorpha intestinalis, E. compressa, Chaetomorpha* sp., *Cladophora* sp., *Hypnea musciformis, Gracilaria verrucosa* and *Acanthophora spicifera*) and sea grasses (such as *Halophila ovalis, Halophila* sp. and *Syringodium isoetifolium*); and act as efficient nursery ground especially for herbivores. Farm construotion in these sites must be discouraged, as it will affect the productivity of mangroves and will spoil the nursery sites.

Predators available in the mangroves that pose threat to the detritus based culture system are *Therapon jarbua* (Forsskal), *Lates calcarifer, Epinephelus tauvina, Elops machnata, Eleutheronema tetradactylum* and *Sphyraena jello*, Cuvier. Extreme care should be taken to avoid these predator organisms entering into culture systems. The complete emptying of pond before stocking and careful screening for their seeds (including eggs, larvae and juveniles) to prevent entry into the ponds when filling with water either by pumping or by sluice mechanisms is essential. Competitors and undesirable organisms existing in the natural waters may gain entry into the culture system such as the mysids (*Mesopodopsis orientalis, M. zeylanica* and *Rhapalophthalmus macropsis*), the pelagic shrimps (*Acetes japonicus, A. indicus* and *A. sibogae*), the scat (*Scatophagus argus*) and polychaetes (*Marphysa* spp.). Proliferous growth of undesired algal weeds especially *Enteromorpha* spp. may cause asphyxiation of culture organisms during night.

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AN APPRAISAL OF THE BIOTIC AND ABIOTIC FACTORS OF THE MANGROVE ECOSYSTEM IN THE COCHIN BACKWATER, KERALA

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ABSTRACT

In view of the significance of the mangrove areas for coastal aquaculture, a reconnaissance survey of the mangrove areas in the Cochin estuarine system was undertaken during 1976-78. The mangroves of Cochin are formative, mostly developing on small reclaimed or natural islands. Environmental characters showed considerable seasonal fluctuations, especially the salinity which in some of the natural ponds in the mangrove area varied from freshwater condition to high saline, mainly due to the monsoonal and tidal influence. The rate of primary production ranged from 0.02 to 2.0 $gC/m^2/$ day which fluctuated from the ambient waters of the estuary.

The dominant mangrove vegetation is constituted by species of *Acanthus, Excoecaria, Clerodendrum, Aegiceras, Avicennia* and *Rhizophora*. Most of the resident fauna include typical mangrove forms such as *Uca* spp. in the upper littoral zone, hermit crabs and *Nautica* spp. in the mid-littoral zone, *Cerethidium* sp. and *Terebralia* sp. on the mud-flats and on the trunks and leaves of mangroves the gastropods *Littorina* sp. are also common. Wood boring organisms such as *Sphaeroma* sp. among crustaceans and teredinids and bivalves were observed to cause damage to the dead roots and trunks of mangrove trees. In tidal pools and creeks of mangroves, concentration of larvae and juveniles of prawns and fishes was observed during certain seasons in conjunction with thick growth of filamentous algae. These seeds are usually collected by local people for the stocking of perennial and seasonal culture fields in and around the area.

INTRODUCTION

IN RECENT YEARS there has been a growing interest and awareness of the mangrove ecosystems as evidenced in the proceedings and deliberations of International and regional symposia and seminars. The mangrove ecosystem usually harbours a characteristic faunal assemblage consisting of resident and migratory animals. It also serves as a breeding and nursery ground for many finfishes and shellfishes. In many parts of the Indo-Pacific, the mangrove areas are proved to be potential sites for culture of fishes, crustaceans and molluscs.

Further, mangrove vegetations colonise on muddysea shores along the borders of the estuaries and typically comprise of highly specialised trees and shrubs mostly belonging to the families, *Acanthaceae, Avicenniaceae, Euphorbiaceae, Myrsinaceae, Rhizophoraceae* and *Verbenaceae*. This vegetation is morphologically and physiologically adapted to withstand vide fluctuations in salinity and hence referred to as ' Halophytes '. The root system of these plants serve to bind the deposited estuarine mud together and stabilize the substrata and prevent erosion. The area consequently becomes a region of accretion and high production. The bacterial and fungal decomposition of the litter fall in the system in considerable quantity results in the high primary production which in turn leads to dense population of secondary and tertiary producers.

A preliminary survey of the mangrove ecosystems was taken up during the years 1976 to 1978 and as the first step, the backwater areas around Cochin was studied and the findings are enumerated in this account.

The authors wish to express their grateful thanks to Dr. E. G. Silas, Director, Central Marine Fisheries Research Institute for the encouragement and guidance given in carrying out this survey and also to Dr. P. V. Ramachandran Nair for helpful suggestions given.

Area of Study

The area of present survey extended from the vicinity of Cochin Harbour in the north, to Perumbalam in the south and the stations, mostly islets were located in the Cochin Backwater system connected to the Vembanad Lake (Fig. 1).

Station 1

Pambaimoola (Local name) is located about 5 km south of Cochin in the backwater system and is mainly a shallow muddy bay which extends to about 800 sq. metres. In swampy pools, dense patches of *Acanthus ilicifolius* dominate and on the shoreward side patches of *Avicennia officinalis* occur.

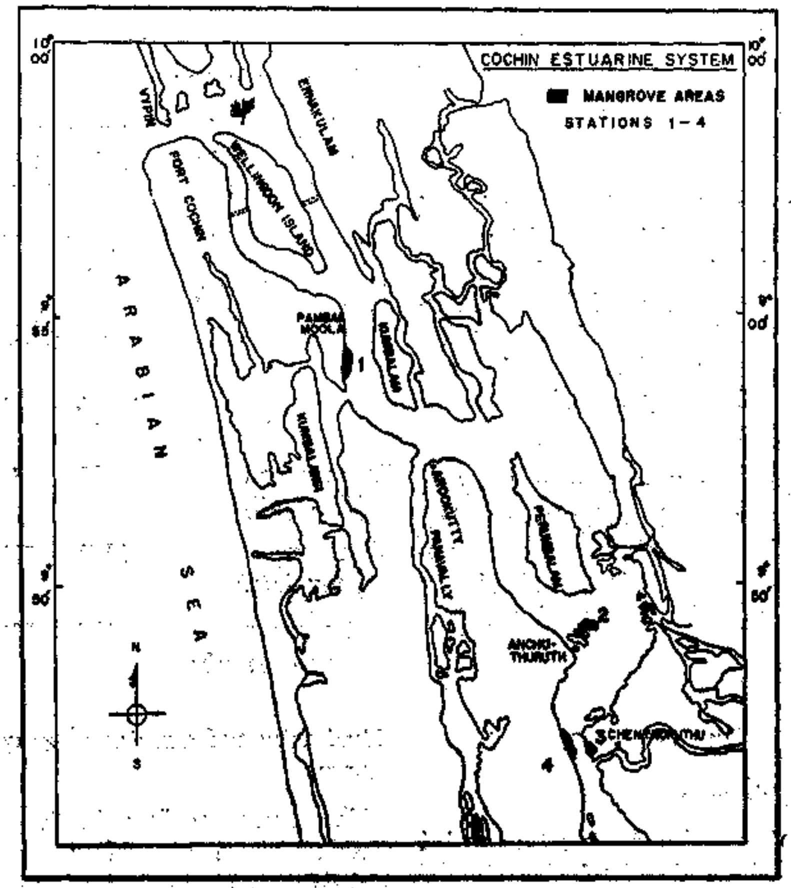

Fig. 1. Cochin Estuarine System with stations surveyed.

Station 2

This is a small island near Perumbalam Island in the Vembanad Lake. The mangrove here consists of low wooded shrubs mostly belonging to genera *Clerodendrum*, *Aegiceras*, *Excoecaria* and *Rhizophora*. During low tide, half of the island is exposed with muddy and sandy flats.

Station 3

This is also a small island (opposite to Chenthuruthu) covered with *Acanthus ilicifolius* in patches, along the fringes. Most part of the island which has a clayey soil has been utilised for paddy-cum-prawn culture by the local people.

Station 4

It has fairly a vast area in the mainland opposite to station 3 and is covered by more terrestrial vegetation due to man-made changes. The mangrove vegetation could be seen intermingled with terrestrial trees and also coconut plantation. A number of shallow ponds occur which serve as good nursery grounds for prawn and estuarine fish larvae.

Routine data were collected every fortnight on the mangrove vegetation, physico-chemical factors of the water such as temperature, salinity, oxygen content, nutrients and primary productivity. Qualitative data on fauna were also collected.

Results

Physico-chemical features

Average monthly surface temperature varied from 25 to 30°C in station 1; 28.2 to 38.3°C in station 2; 24.2 to 36.5°C in station 3 and 31.2 to 41.0°C in station 4. Monthly average values of surface salinity varied from 0.77‰ to 29.0‰ (station 1), 0.21 to 29.21‰ (in station 2), 0.68 to 30.26‰ (Station 3) and 0.90‰ to 29.0‰ in station 4.

Dissolved oxygen content in the mangrove creeks showed seasonal changes and ranged from 1.03 to 5.03 ml/l (station 1); 2.02 to 5.6 ml/l (station 2); 3.15 to 6.33 ml/l (station 3) and 2.91 to 5.6 ml/l in station 4.

Nutrients	*Stn.* 1	*Stn.* 2	*Stn.* 3	*Stn.* 4
Nitrite N (μg at/l)	0.74-0.85	0.35-0.85	0.40-0.59	0.43-0.82
Phosphate (μg at/l)	1.0-1.52	0.00-1.68	0.00-2.27	0.00-1.59
Carbon (mgC/g)	21.2-27.69	16.0-26.30	21.8-31.84	15.2-1.82

Primary production

Primary productivity was estimated by both oxygen technique and ^{14}C technique. In general, the values ranged from 240-2150 mgC/m³/day in different months of the year. The seasonal variation in production is presented below.

	Production mgC/m³/day			
	Stn. 1	*Stn.* 2	*Stn.* 3	*Stn.* 4
Pre-monsoon (Jan-April)	900	450	620	665
Monsoon (May-Aug.)	1370	510	610	370
Postmonsoon (Sept.-December)	805	560	630	455

Distribution and zonation of mangrove flora and fauna

The mangrove flora in the tidal zone of station 1 was dominated by *Acanthus ilicifolius* and the rest consisted of *Clerodendrum inerme*, *Rhizophora mucronata* and *Avicennia officianalis*. The upper zone is colonised by typically terrestrial trees such as *Thespesia pupulnea*.

The muddy outpocket which is often exposed during low tide, was inhabitated by *Terebralia* with a density of 15-25 no./sq.m. This area is used for soaking timber and is highly polluted.

At the upper fringe of the swampy area *Nerita* and *Littorina* could be found on hard substrata and *Crassostrea* and barnacles in the lower zone. Burrowing polychaetes and egg case of *Marphysia* were also common. Occasionally *Modiolus* sp. were observed as attached to *Terebralia*. A few nudibranch were collected from the leaves of *Acanthus*.

Above the intertidal zone crabs belonging to the families *Portunidae*, *Ocypodidae* and *Grapsidae* are commonly found. Juveniles of *Haplocheilus*, *Therapon*, *Ambassis* and of the prawns *Penaeus* and *Metapenaeus* occur commonly in the swampy pools.

The southern side of station No. 2 is populated by low shrubs *Clerodendrum enerme*, *Aegiceras corniculatum*, *Excoecaria agallocha* and occasional stands of *Rhizophora mucronata*.

Hydromedusae such as *Eirene* sp. were collected in good numbers during summer months. In the sandy flats, tube dwelling polychaetes could be observed. Young ones of mussels and *Modiolus* occurred on dead mangrove trunks. Wood boring bivalves and crustaceans were noticed on certain occasions on mangrove stumps and breathing roots. *Cerethedium* usually occur in large numbers during March-May. Juveniles of *Therapon* *Ambassis* and prawns occur in good numbers in the tidal pools among mangrove vegetation.

The 3rd station was dominated by the following vegetation : *Acanthus ilicifolius*, *Aegiceros corniculatum*, *Clerodendrum inerme* and *Rhizophora mucronata*. This was backed by terrestrial forms like *Vitex* sp., *Ipomea biloba*, *Phyllanthus* sp. and *Acrostichum aureum*.

Boring bivalves were commonly observed in the dead roots of mangroves. During certain months anemones and gastropod *Ilobium* sp. and its egg masses could be observed in the exposed muddy areas. Juveniles of *Penaeus indicus*, *Metapenaeus dobsoni* and *M. monoceros* were usually observed in the creeks of mangrove area. During summer months, when the salinity is high, prawn culture is practised in this island.

The station 4 has a good compliment of mixed mangroves such as *Rhizophora mucronata*, *Bruguiera cylindrica*, *Aegiceros corniculatum*, *Clerodendrum inerme*, *Excoecaria agallocha* and *Acrostichum aureum*. Terrestrial forms such as *Calophyllum inophyllum*, *Ipomea biloba* and *Eriocolon* sp. also occur. In general, the mangrove vegetation exhibit luxurient growth in the post-monsoon months with flowering in September to December period.

In station 4 species of *Terebralia* occur only in small numbers and in a scattered manner. Above the intertidal zone crabs such as *Uca*, *Scylla serrata*, *Sesarma* and *Metapograpsus* could be found in different months. In the creeks and ponds, juveniles of *Haplocheilus*, *Ambassis*, *Etroplus*, gobiids, *Tetradon* and *Batrachus* could be found in different seasons.

The distribution of flora and fauna commonly occuring in the different mangrove stations could be summarised as follows :

Habitat	Flora	Fauna
Mid-tidal zone	*Acanthus ilicifolius*, *Excoecaria agallocha*, *Aegiceros corniculatum* and *Clerodendrum inerme*	*Scylla serrata*, *Uca annulipes*, *Uca vocans*, *Sesarma lanatum*, *Sesarma plicatum*, *Metapagrapsus messor*, hermit crabs, burrowing amphipods, barnacles, wood boring bivalves, *Littorina* sp. and *Nerita* sp.
Upper tidal zone	*Avicennia officinalis*,	*Terebralia* sp., *Cerethedium* sp., small gastropods,

Habitat	Flora	Fauna
	Rhizophora mucronata and *Bruguiera cylindrica*	polychaetes and diogenes.
Tidal pools & creeks	*Acrostichum aureum*, *Eriocolon* sp., *Cyperus* sp. and *Ipomea*	Amphipods, alphaeids, small *Neptunus*, juveniles of *P. indicus*, *M. dobsoni* *M. monoceros*. *Etroplus maculatus*, *E. suratensis*, *Ambassis dayi* and *A. commersoni*
Terrestrial*	*Thespesia pupulnea*, *Vitex* sp., *Phyllanthus* sp. *Calophyllum inophyllum* and *Panicum* sp.	

DISCUSSION

The mangroves in the Cochin Backwater system as it is observed now could be described as isolated patches which have undergone degradation due to man made changes. Blasco (1975) pointed out that out of the estimated 70,000 ha of mangrove areas in India, Kerala Backwaters have only a vestige of less than 100 ha. Although the backwater channels are shallow, narrow and well connected to the sea and the adjacent terrain with copious rainfall annually, mangrove development has been very much restricted. The areas bordering the canals are over populated and what was once a mangrove area has been converted into coconut groves and paddy fields or prawn culture fields.

Wide seasonal fluctuations in the physicochemical factors have been noticed in the mangrove areas investigated. The Cochin Backwater where these mangrove stations are located, is also subjected to considerable fluctuations in the above factors (Qasim *et al.*, 1969).

Qasim (1970) estimated gross production in the estuary as ranging from 270-295 gC/m^2/year and the annual consumption of the zooplankton herbivores as only about 30 gC/m^2. This indicated the availability of large surplus food in the estuary and the connected mangrove area which may perhaps be utilized by other members of the ecosystem such as herbivorous fishes (mullets) and omnivorous detritus feeders such as prawns.

Commenting on the faunal characteristics of Asian mangroves Morton (1978) has observed, that a wide range of animals including worms (*Phascolosoma*), snails (*Telescopium*, *Cerethidia* and *Terebralia*), bivalves (*Gelonia*, *Enigmonia*, *Pharella*, *Modiolus*), crustaceans (*Sesarma*, *Uca*, *Ilyoplax*, *Scylla*, *Thalassina*), fishes (*Periopthalmus*, *Ambassis*, *Scatophagus*, *Platycephalus*) and protochordates (*Balanoglossus*) are usually found in the mangrove habitat and they are capable of tolerating wide fluctuations in salinity. The mangrove soils and mud are acidic and deficient in calcium salts, so that the back of the mangroves are colonised by *Gelonia* or by pulmonate snails *Ellobium*, *Melampus* and *Cassidula*. On the trunks and roots of mangroves could be observed representatives of seashore life such as lichens, littorine snails, barnacles and mangrove bivalve *Enigmonia*. These assemblages constitute a hard shore niche in an otherwise soft shore environment and the principle of inter-tidal zonations could be observed. The tides indeed are responsible for affecting, creating and maintaining the zonation of animal community.

Saseekumar (1978) has pointed out that the detritus foodweb based on mangrove plant material is more complex in the tropical areas due to the presence of more species of crustaceans, gastropods and fishes. The examination of gut contents of these fishes, some of them economically important, consisted of mangrove

* The terrestrial zone was completely dominated by terrestrial angiosperms.

detritus and mangrove dwelling invertebrates. In the case of mullet, 40% of the diet consisted of detritus and in *Haplocheilus melastigma* it was over 80%, for *Plotosus caninus*, the chief food consisted of mangrove snail *Cerethidia*. It is interesting to observe that these finfishes community occur in the Cochin mangroves also.

In the course of our observations on the mangrove areas of Cochin, on many occasions, juveniles of prawns were observed in the mangrove creeks and ponds, particularly associated with filamentous algae along the shore. It is well known that these areas serve as nursery grounds for the juvenile stages of prawns which feed on detritus rich benthos and flora of micro-algae. Saseekumar (1978) has drawn attention to the fact that the prawn catches in Malaysia were greater along the mangrove-rich west coast than the east coast. He has also drawn attention to similar linear relation between prawn production and acreage of mangroves already established in Indonesia. Though it may not be possible to establish such a relationship in the Cochin Backwater, the contributory factors from mangrove areas cannot be ruled out.

The objective of this account is to focus attention on the structure of the mangroves in the Cochin estuarine system and the characteristics of resident and migratory fauna. The seasonal fluctuations in the physico-chemical features and general productivity of the mangrove areas are influenced by the general dynamics of the estuarine system of the whole area.

Being overpopulated, the coastal areas have gradually been transformed to many productive uses such as coconut plantation, paddy-cum-prawn filtration and perennial prawn culture practices. In this process the fragile mangrove ecosystem has suffered depletion, a fact which must be viewed with concern from the point of view of conservation. That the mangrove creeks and swamps are utilised by the local population as the site for collection of seeds of cultivable finfishes and shellfishes, points to the ecological significance of mangroves for coastal aquaculture.

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PRIMARY PRODUCTION AND PHYTOPLANKTON PIGMENTS IN AN ESTUARINE ENVIRONMENT

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ABSTRACT

The paper highlights the results of the studies carried out on primary production and phytoplankton pigments in Vellar Estuary during 1968 and 1969.

The seasonal cycle of gross and net photosynthesis presented a similar bimodal type of variation with minimum in November and maximum in April. The mean monthly values of gross photosynthesis for surface water varied from 19.51 (November) to 343.55 $mgC/m^3/hr$ (April) during the two years. For bottom waters the range of variation was from 18.35 to 80.04 $mgC/m^3/he$. The mean monthly values were maximum in April (320.1 $mgC/m^3/hr$) and minimum in November (23.38 $mgC/m^3/hr$). Bottom values were lower than surface values with minimum in November (11.52 $mgC/m^3/hr$) and maximum in April (123.29 $mgC/m^3/hr$). The estimated or adjusted net prouction ranged from 275.22 to 3773.6 $mgC/m^3/day$. The ratio of net to gross production varied from 0.4 to 0.9.

The bimodal seasonal cycle in gross and net production with markedly higher values in warmer months may be ascribed to rapid regeneration of nutrients from bottom waters due to increased bacterial metabolism at higher temperature. The ratio of net production to gross production approached 0. which indicated that nutrients were not the chief limiting factors in this estuary.

The seasonal cycle of Chlorophyll 'a' showed a bimodal oscillation similar to photosynthesis values. Chlorophyll 'a', 'b' and 'c' varied from 2.15 to 21.3 mg/m^3, 0.26 to 3.88 mg/m^3 and 0.55 to 7.97 mg/m^3 respectively.

Chlorophyll 'a' always exceeded Chlorophyll 'c' values whichs heds light on the richness of phytoplankton in the estuary. The relationship between net production and chlorophyll 'a' was highly significant (r=0.7) and the dead or inactive Chlorophyll was found to be negligible in the estuary. The yearly numerical value of assimilation number *i.e.* carbon fixed/chlorophyll 'a' was found to be 11.3 indicating that the esturaine waters are rich in nutrients. Chlorophyll 'a' variation paralleled that of photosynthesis with maximum in April and minimum in November.

Chlorophyll 'b'/'a' was significantly high during monsoon months when the fresh water plankters such as *Euglena* and *Volvox* predominated. The variation in chlorophyll 'c'/'a' paralleled that of carotenoid / Chlorophyll 'a' with maximum in August and minimum in April. A positive correlation between the occurrence of dinoflagellate (*Noctiluca*) bloom and the ratios of chlorophyll 'c'/'a' and carotenoid/chlorophyll 'a' was observed in the present study. The Vellar Estuary is having a constant influx of sea water from semidiurnal tides and incursion during summer and fresh water during monsoon. This is reflected clearly in the pattern of seasonal variation of photosynthesis and phytoplankton pigments.

INTRODUCTION

One of the most intriguing problems of biological oceanography today is the characterization of annual cycle of primary production and Phytoplankton pigments in natural bodies of water and its relation to environmental parameters (Gilmartin, 1964). The measurement of primary production is of great importance because of its significance to Fisheries Science and larger problems of aquatic ecology. In studies related to marine or estuarine food chains the estimation of standing crop of phytoplankton becomes a necessary pre-requisite than that of carbon assimilation, for animals need food and therefore the chlorophyll estimations indicate total plant material available at the primary stage of food chain. Further, phytoplankton pigments and the possible ratios between different pigments play a key role in the taxonomic identification of phytoplankton species. As the information pertaining to these aspects of an estuarine environment is scanty, a study of primary production and phytoplankton pigments in Vellar Estuary spread over a period of 2 years from 1968 January to 1969 December, was carried out.

I have great pleasure in expressing my sincere thanks to Prof. R. Natarajan, Director, Centre of Advanced Study in Marine Biology for his keen interest, encouragement and facilities. My thanks are due to late Prof. R. V. Seshaiya, Former Director under whose guidance this work was started initially. I wish to record my deep indebtedness to Prof. V. K. Venugopalan for critically going through the manuscript and offering valuable suggestions. My thanks are also due to the University Grants Commission, New Delhi for award of a Junior Research Fellowship during the tenure of my research work.

Material and Methods

Primary production measurements were made using Gaarder and Gran's (1927) light and dark bottle method as described by Strickland and Parsons (1968). Samples of water for measuring primary production were collected from surface and bottom and incubation was made for 3 hours. Photosynthesis and respiration were calculated from changes in dissolved oxygen in the light and dark bottles after incubation. Dissolved oxygen was estimated by Winkler's titration method from which gross and net photosynthesis were calculated and expressed as $mgC/m^3/hr$.

For the estimation of phytoplankton pigments, only surface samples were collected. The spectrophotometric method described by Richards and Thompson (1952) as modified by Creitz and Richards (1955) was followed for evaluating different fractions of chlorophylls *viz.*, chlorophyll 'a', 'b', 'c' and also carotenoids.

Results

Gross Production

The seasonal cycle of gross production is shown in Fig. 1. The annual cycle of gross production of both surface and bottom waters presented a bimodal oscillation. Gross production increased from a minimum in January to a maximum in April which was followed by a decline till June. Gross production increased again to a secondary maximum of much smaller magnitude in July. A steady decline in gross production was observed from July until the end of the year and showed its annual minimum in November. The mean monthly gross production for surface and bottom waters during 1968 ranged from 33.8 (November) to 343.55 $mgC/m^3/hr$ (April) and from 19.51 (November) to 80.04 $mgC/m^3/hr$ (April) respectively.

During 1969 the pattern of variation in gross production was similar to that observed during 1968 with maximum values in April and minimum in November. The maximum mean monthly values recorded for surface and bottom waters were 339.4 and 107.4 $mgC/m^3/hr$ respectively. The mean monthly minimum observed for surface and bottom were 33.39 (November) and 18.35 $mgC/m^3/hr$ (November).

Net Production

The mean monthly values for net production are shown in Fig. 1. The seasonal variations in net production for surface and bottom waters were similar to that of gross production with maximum values occurring in the month of April and minimum in November. During 1968 surface values of net production ranged from 12.38 to 66.01 mgC/m³/hr. In the succeeding year surface and bottom values showed a similar trend of variation with a primary peak occurring in April and a secondary one in July. The range of variation for surface and bottom water was from 23.38 to 311.40 mgC/m³/hr and from 11.52 to 123.29 mgC/m³/hr respectively.

the succeeding year it varied from 0.4 to 0.9. Total respiration as a percentage of gross photosynthesis ranged from 13.0 to 37.3% in 1968 and from 11 to 36% during 1969.

Distribution of Chlorophylls

The distribution of chlorophylls 'a', 'b' and 'c' are shown in Fig. 2. In general all the three chlorophyll pigments showed similar variations with a primary peak in April and a secondary peak in July. From July onwards chlorophyll values decreased and reached a minimum in November.

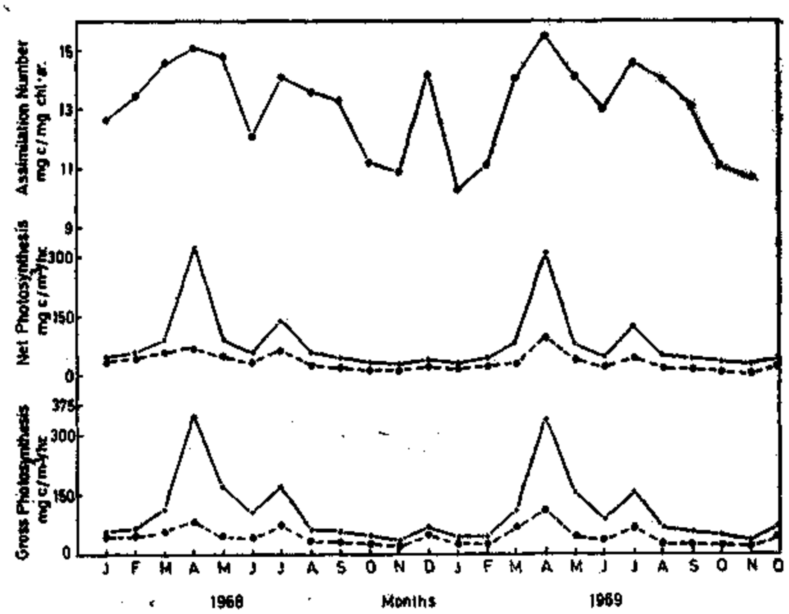

Fig. 1. Seasonal variations in gross photosynthesis, net photosynthesis and assimilation number. ·——· Surface ·----· Bottom

The estimated net production or adjusted net production calculated by subtracting the respiratory loss that occurs during night (10 hrs) from the day time net production ranged from 284.4 to 4007.1 mgC/m³/day and from 275.22 to 3773.6 mgC/m³/day during 1968 and 1969 respectively.

N. P. : G. P. Ratio

The ratio of net production to gross production ranged from 0.5 to 0.9 in 1968 and in

The mean monthly concentration of chlorophyll 'a' ranged from 2.23 to 21.3 mg/m³ during 1968 and 2.15 to 20.0 mg/m³ in the succeeding year. Chlorophyll 'b' varied from 0.27 to 3.88 mg/m³ in 1968 and from 0.26 to 2.35 mg/m³ in 1969. Chlorophyll 'c' had a range of variation from 0.62 to 6.28 mg/m³ in 1968 and from 0.55 to 7.97 mg/m³ in 1969.

Carotenoids

The seasonal fluctuations in the carotenoids are shown in Fig 2. The carotenoid pigments also showed 2 peaks similar to chlorophyll peaks. The primary peak occurred in April and secondary peak in August in 1968 and 1969. The mean monthly values of carotenoids during 1968 and 1969 ranged from 0.73 to 8.32 and from 0.47 to 9.28 MSPU/m^3 respectively.

Carotenoid : Chlorophyll 'a' ratio

The trend of variations in carotenoid chlorophyll 'a' was similar to that of chlorophyll 'c'/chlorophyll 'a' ratio with high values occurring in August. The ratio of carotenoid: chlorophyll 'a' varied from 0.32 to 1.20 in 1968 and from 0.21 to 1.3 in 1969 (Table 1).

Assimilation number (photosynthetic carbon fixed chlorophyll 'a')

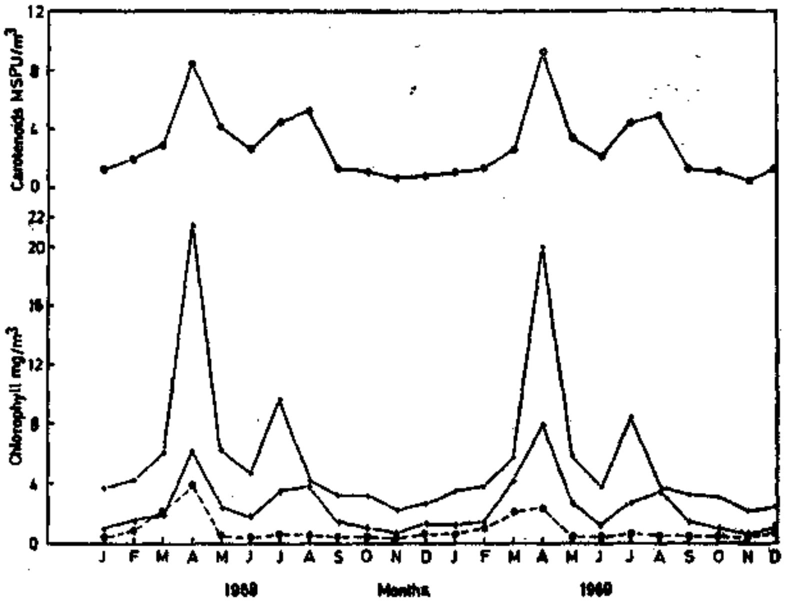

Fig. 2. Seasonal Variational in chlorophyll 'a', 'b' 'c' and Carotenoids.
.———. Chlorophyll 'a' .-----. Chlorophyll 'b' ×———× Chlorophyll 'c'

Chlorophyll 'b' : 'a' ratio

The ratio of chlorophyll 'b'/'a' varied from 0.06 to 0.33 in 1968 and from 0.06 to 0.35 in 1969. The ratio was found to be very low during the months of May, June and July and high in March in both the years (Table 1).

Chlorophyll 'c' : 'a' ratio

The chlorophyll 'c'/'a' presented marked variations with maximum values in August. The ratio of chlorophyll 'c'/'a' varied from 0.25 to 0.9 and from 0.25 to 0.97 during 1968 and 1969 respectively (Table 1).

Interesting trends were seen in the seasonal variation in assimilation number with maximum values in April and minimum values in November (Fig. 1). An increase in assimilation number from January to April followed a similar increase in gross and net production. Assimilation number declined in June and increased again to a second maximum in July. From July a decrease in the ratio was noticed with minimum in November. The seasonal variation in assimilation number paralleled that of photosynthesis, the maximum value (15.5) occurring in April 1969 and minimum (10.3) in

TABLE 1. *Mean monthly variations in pigment ratio during* 1968

	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
Chlorophyll 'b'/'a' ..	0.11	0.20	0.33	0.18	0.06	0.08	0.05	0.11	0.10	0.08	0.27	0.21
Chlorophyll 'c'/'a' ..	0.25	0.30	0.30	0.29	0.38	0.37	0.35	0.9	0.43	0.29	0.27	0.47
Carotenoid 'a' ..	0.33	0.44	0.45	0.39	0.68	0.58	0.46	1.2	0.41	0.34	0.32	0.37
Mean monthly vatiations in pigment ratios during 1969												
Chlorophyll 'b'/'a' ..	0.15	0.24	0.35	0.11	0.06	0.08	0.06	0.12	0.10	0.10	0.12	0.20
Chlorophyll 'c'/'a' ..	0.32	0.37	0.69	0.39	0.47	0.35	0.31	0.97	0.42	0.29	0.25	0.47
Carotenoid/Chlorophyll 'a' ..	0.25	0.35	0.43	0.41	0.58	0.53	0.51	1.30	1.29	0.32	0.21	0.45

January 1969. The range of assimilation number was from 10.8 to 15.02 in 1978 and from 10.3 to 15.5 in 1969.

DISCUSSION

The yearly cycle of gross and net production in Vellar Estuary showed 2 peaks (Fig. 1) corresponding to the seasonal variations in the chlorophyll 'a' concentration. Maximum production was recorded during early summer (April), a period of fairly high water temperature and salinity while minimum values were observed during monsoon months (September to November). Williams (1966) pointed out that such type of annual cycles in the production of marine plankton with higher values in summer are characteristic of shallow waters particularly of temperate embayments. Thayer (1971) also observed a similar pronounced seasonal cycle of phytoplankton production which paralleled water temperature in some estuaries at Beaufort. The annual cycle of primary production in Vellar Estuary revealed a bimodal curve with two peaks as has been reported by Gilmartin (1964) in the British Columbia fjord.

The most interesting feature in the present observation was with regard to the ratio of N.P. : G.P. Ketchumet *et al.* (1958) showed that the ratio of N.P. : G.P. in a healthy population should approach unity if respiration falls between 5 to 10% of gross photosynthesis. They also had put forward that this ratio was indicative of the actual physiological state of phytoplankton population which arises due to nutrient availability or deficiency. At times of nutrient deficiency the ratio would approach zero. In the present study the range of respiration as a percentage of gross photosynthesis was found to vary from 13 to 37%. The ratio of N.P. to G.P. was found to be within a range of 0.5 to 0.9. These values agree well with the observations of Qasim *et al.* (1969) for the Cochin Backwaters where respiration was 20 to 45% of G.P.S. and G.P.S. to N.P.S. ratios were found to range from 0.55 to 0.75. The fluctuations of this ratio within such a narrow range as observed in Vellar Estuary signifies that nutrients were not the chief limiting factors of primary production.

The present study on pigments (chlorophylls) (Fig. 2) showed certain interesting results. Since chlorophyll 'a' is an active photosynthetic pigments an attempt was made to relate chlorophyll 'a' to the photosynthesis values obtained in the present study. The concentration of chlorophyll 'a' was characterised by high degree of variability. The seasonal cycle of chlorophyll 'a' was well pronounced with two maxima occurring in the months of April and July which paralleled fluctuations in gross and net production values. Minimum values observed in November coincided with minimum values of net production, dearth of phytoplankton, and low salinity, while higher values encountered in April paralleled similar high values of net production, abundance of phytoplankton and higher salinity. This supports the observations of Burkholder and Sieburth (1961) who also observed a similar relationship between chlorophyll 'a' and net photosynthesis values in Gerlache and Bransfield Straits of Antarctica.

The mean monthly values of chlorophyll 'a' varied from 2.15 to 21.3 mg/m^3. Burkholder and Sieburth (1961) reported chlorophyll 'a' values up to 27 mg/m^3 in the neritic Gerlache Strait. Burkholder and Mandelli (1965) observed during summer blooms chlorophyll 'a' maxima as high as 25 to 27 mg/m^3 in the same area. The range of values observed in the present study were however higher than those observed by Humphrey (1962) who reported a range of 0.02 to 1.09 mg/m^3 for Pacific waters.

Very little information is available with regard to distribution of pigments in Indian waters. Radhakrishna (1969) observed an average value of 19.5 mg/m^3 for chlorophyll 'a' for the waters of southwest coast of India. Shah (Personal communication) found that in an inshore station off Cochin the chlorophyll 'a' values ranged from 0 to 8.0 mg/m^3 for mangrove region which compares favourably with the present observation.

In the present study chlorophyll 'a' concentration always exceeded chlorophyll 'c' values. However Qasim and Reddy (1967) observed higher 'c' values for Cochin Backwaters during monsoon which they attributed to turbidity.

such as *Euglena*, *Volvox*, etc. The qualitative analysis of phytoplankton in the present study revealed the predominance of *Euglena*, *Volvox*, etc. during monsoon months *i.e.* November and December which probably would account for an increase in chlorophyll 'b'/chlorophyll 'a' ratio during these months.

The seasonal variation of chlorophyll 'c'/chlorophyll 'a' ratio presented certain interesting features. The ratio was low at the commencement of the phytoplankton bloom in April, but gradually increased with the decline in phytoplankton population. Platt and Subba

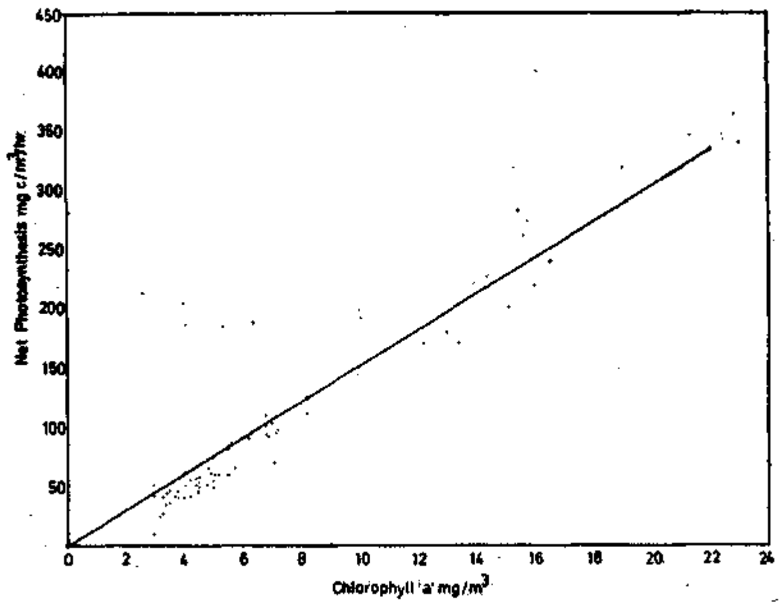

Fig. 3. Relationship between Primary Production and chlorophyll 'a' during 1968.

A wide variation in the ratios between various fractions of chlorophylls was observed throughout the period of investigation (Table 1). This was specially so with regard to chlorophyll 'b'/chlorophyll 'a' ratio. In the Vellar Estuary the chlorophyll 'b'/'a' ratios were generally high during monsoon months. Similar observations were also reported by Humphrey (1960) for the waters of Australia. Further it was reported by Wright (1964) that chlorophyll 'b' was the predominant pigment of freshwater forms

Rao (1970) also reported a similar feature at St. Margarets Bay. Similar pattern of variation in the chlorophyll 'c'/chlorophyll 'a' ratio with the age of the population was apparent in the culture experiments of Humphrey (1963 a) and Madgwick (1966). Another interesting observation with regard to present study was that a maximum ratio of 0.9 and 0.97 were obtained in August 1968 and 1969 in the month of August which coincided with *Noctiluca* bloom that appeared in this month. It might be pointed out that a culture ratio of 0.9 was obtained with dinoflagellate population by Humphrey (1963 a) and Madgwick (1966) which was closer to the chlorophyll 'c'/chlrophyll 'a' ratio observed in the Vellar Estuary.

The ratio of carotenoid/chlorophyll 'a' increased from January to March and decreased to April. The maximum ratio of carotenoid/chlorophyll 'a' in August coincided with the abundance of dinoflagellates and the high chlorophyll 'c'/chlorophyll 'a' ratio.

chlorophyll 'a' and net photosynthesis by Edmondson (1955) in laboratory experiments at Woods Hole with enriched phytoplankton. Radhakrishna *et al.* (1978) also reported a highly significant positive relationship between net photosynthesis and chlorophyll 'a' (r = 0.59) for the Southeast Arabian Sea similar to what has been observed in the present study.

Since the regression line approached the origin (Fig. 3, 4) dead or inactive chlorophyll in the Vellar Estuary appeared to be negligible.

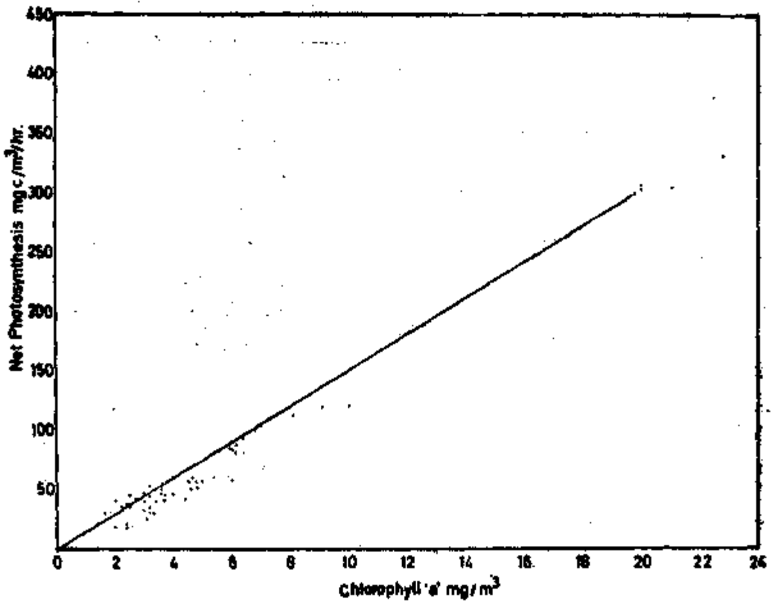

Fig. 4. Relationship between Primary Production and chlorophyll 'a' during 1969.

A plot of net photosynthesis against chlorophyll, 'a' (Fig. 3, 4) revealed that an increase in chlorophyll 'a' was followed by a corresponding increase in net photosynthesis. A positive relationship was obtained between the quantity of carbon assimilated and the amount of chlorophyll 'a' present (r = 0.72). A somewhat lesser correlation was observed (r = 0.45) between net photosynthesis and chlorophyll 'a' by Qasim *et al.* (1969) for Cochin Backwater. However a much closer correlation of 0.86 was obtained between

Anderson (1964) also reported that dead or inactive chlorophyll was negligible at all times off the coasts of Washington and Oregon.

The seasonal Variation of the assimilation numbers (The ratio of carlon fixed/chlorophyll 'a') presented certain interesting features. In the present study, the seasonal variations in the assimilation number increased with an increase in temperature from January to April and attained its maximum in April, a period of maximum photosynthesis. Such a wide seasonal change in the assimilation number with maximum value in warmer months suggest the influence of temperature on the phytoplankton production as pointed out by Burkholder and Burkholder (1967). Odum *et al.* (1958) pointed out that higher temperature speeded up reactions and allowed faster regeneration rates that probably caused higher assimilation numbers.

The nutrient relationships within the estuary could be understood from the yearly numerical average value of assimilation number. Curl and Small (1965) suggested that assimilation ratios of 0-3 indicated nutrient depletion, 3 and 5 indicated borderline nutrient deficiency and 5 and 12 indicated nutrient rich waters. In the present observation the yearly numerical average of assimilation numbers was found to be 11.3 from which it is quite clear that estuarine waters was rich in nutrients. Radhakrishna *et al.* (1978) observed in the onshore waters of North American Sea that the assimilation number ranged from 11-34 and averaged 22. This would indicate that shelf productivity was not only due to chlorophyll ' a ', but also to other accessory pigments of nannoplankton which were found to be rich in chlorophylls, Xanthophylls and Carotenoids. The assimilation number in the north eastern Arabian Sea varied from 24 at the deepest station to 208 at the shallowest station and offshore the assimilation number averaged 22 varying from 11 to 34. (Radhakrishna *et al.*, 1978). This would indicate that shelf productivity was not only due to chlorophyll ' a ', but also due to other accessory pigments.

The Vellar Estuary is a tidal river with semidiurnal tides and is always open to the sea. The estuary goes through a period of drought from February to July and a period of freshwater scouring during north east monsoon season of September to December. The yearly cycle of gross and net production in the Vellar Estuary showed a well defined seasonal cycle with 2 peaks corresponding to the seasonal variation in chlorophyll ' a ' pigment. Maximum values of photosynthesis were recorded in April, a period of fairly high water temperature and salinity. Minimum values of production were encountered in November when a dearth of phytoplankton was recorded. From the yearly numerical average value of assimilation number (11.3) obtained in the present study it can be deduced that the Vellar Estuary was rich in nutrients (Curl and Small, 1969). A close correspondence was obtained between carotenoid/chlorophyll ' a ' ratio, chlorophyll ' c '/ chlorophyll ' a ' ratio and fluctuations in dino flagellate abundance.

The Vellar Estuary is kept in constant influx due to semidiurnal tides and by penetration of sea water during summer and subjected to freshwater discharge during monsoon. This is to some extent reflected in the pattern of seasonal variation of primary production and phytoplankton pigments. Variability in time and heterogeneity in space which are naturally inherent in estuarine parameters make it a dynamic environment which is clearly borne out in the present study.

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PRODUCTIVITY OF DIFFERENT MANGROVE ECOSYSTEMS

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ABSTRACT

This paper embodies the results of field studies conducted on productivity in three different mangrove areas, *viz.*, Cochin Backwater, Killai Backwater and Andaman Nicobar Islands. The rate of production varied in these areas, but generally indicated a good production rate. The energy inputs from various sources into the ecosystem and the process of conversion are discussed in the light of an overall energy budget available. The productivity of adjacent marine environments is also discussed in the light of their suitability for development of mariculture practices.

INTRODUCTION

THERE is increasing awareness in our country and elsewhere on coastal aquaculture as a measure for increasing production of finfishes and shellfishes. As an essential prerequisite, it has become necessary to survey suitable areas for mariculture in estuarine and lowlying areas and assess the productivity of such areas, so that the investigations will provide a clue to the stocking capacity in the areas chosen for culture practices. This would also enable an assessment of the fluctuations in potential yield of finfish and shellfish stock per unit area.

It is now well known that mangrove areas which are found in estuarine and coastal regions are potential source of organic detritus that enrich the estuarine and inshore regions, in the vicinity of which aquaculture and sea-farming are undertaken. Heald and Odum (1970) has drawn attention to the magnitude of organic productivity in the Florida mangrove creeks. The mangrove areas generally provide detritus-rich food for a number of estuarine organisms such as mullets, *Chanos*, *Etroplus*, prawns, oysters and mussels, in addition to providing shelter for the juvenile stages of these groups.

In India, mangrove formations are rich in Sunderbans, Godavary Delta, Andaman-Nicobar Islands and Kauvery-Delta of Tamil Nadu. As a part of the ecological investigations on mangrove areas carried out by Central Marine Fisheries Research Institute, primary productivity in the mangrove areas were estimated in Cochin Backwater (Kerala), Killai Backwater (Tamil Nadu) and Andaman Nicobar Islands, and the present paper embodies the results of these studies.

The authors are grateful to Dr. E. G. Silas, Director, Central Marine Fisheries Research Institute, Cochin for the guidance and encouragement given to this research programme. They are also very thankful to Dr. P. V. Ramachandran Nair and Dr. K. J. Mathew for their suggestions.

MATERIAL AND METHODS

Light and dark bottle oxygen technique has been used for estimating the productivity with occasional cross checks by ^{14}C technique

(Steemann Nielsen, 1952). In the ^{14}C technique, 5 μg of $NaH^{14}CO_3$, 1 ml was added to samples taken in 60 ml reagent bottles. The samples were incubated in natural light for 2 hours. Activity of the filter was determined on a Geiger Counting System having an efficiency of 3.2%. The use of ^{14}C was highly restricted in the experiments because of the high variability in salinity and temperature in these ecosystems which in turn governs the total CO_2 concentration of the water. The sampling has been done only at the surface waters and the incubation has been carried out under identical conditions of temperature and light. In view of the limited depth of the mangrove waters, it was not felt necessary to conduct sampling throughout the water column. As the light penetration takes place upto the bottom, there is not much limitation regarding the available energy for photosynthetic activity. So the availability of nutrients as well as the process of regeneration are considered the major criteria governing the productivity. The oxygen technique of production per unit volume has been computed assuming PQ as 1.25.

Areas investigated

The estuarine system of Cochin has a total coverage of about 300 sq km. The mangrove formations are restricted and of a patchy nature in some islands in the backwater system and in some reclaimed areas near the Cochin Bar-mouth. The stations studied during the present investigation are situated on the southern part of Cochin near Perumbalam. The mangrove vegetation showed typical forms such as *Avicennia officinalis, Rhizophora mucronata, Bruguiera cylindrica, Excoeccaria agallocha, Aegiceras corniculatum, Acanthus ilicifolius* and *Clerodendron inerme*.

At Killai area, in the Coleroon and Vellar estuaries near Porto Novo (Tamil Nadu), dense formations of mangrove vegetation are found in an area spreading to about 1000 ha. The mangrove vegetation is comparatively rich with the formations of *Rhizophora mucronta, R. apiculata* in the inter-tidal zones and other species such as *Avicennia marina, A. officinalis, Bruguiera cylindrica, Ceriops decandra* and *Excoeccaria agallocha* in the immediate background. Species such as *Aegiceras corniculatum* and *Lumnitzera racemosa* are usually found growing between the prop roots of *Rhizophora*. The vegetation shows distinct zonation and spatial distribution, as a result of mixing of freshwater and brackish-water. It is estimated that the litter production is about 3 tonnes/ha/year in this mangrove area (Sundararaj, 1978). This gives an indication of protein rich detritus matter available for fishes and prawns which are abundant in the area.

The Andaman Nicobar Islands consist of several islands extending to about 800 km between lat. 6°40′ and 13°41′N. These islands offer a vast coast line where mangrove vegetation thrives under typical tropical conditions. Because of the thin population of browsing cattle and less human interference, the mangroves of these islands are well preserved by nature as compared to regions like Gujarat where man has continuously exploited them for fodder and firewood. The mangrove area of the islands is estimated to be about 1,15,200 ha and within this ecosystem live a host of animals such as crabs, molluscs, and juveniles of prawns and fishes.

As regards the mangrove vegetation in the Islands, *Rhizophora mucronata* and *R. apiculata* exhibit dense formation along the border of bays and creeks. The tree forms grow to heights of 10-15 m. Behind the inter-tidal zone *Bruguiera parviflora* and *B. gymnorrhiza* are common. In certain pockets, *Sonneratia caseolaris, S. alba, Avicennia marina, Aegiceras corniculatum* and *Nypa fruticans* occur in good numbers.

Table 1 gives the values of primary production in different mangrove areas investigated.

Within the productivity range mentioned above for Cochin estuarine system, the primary peak is observed usually in the month of June and a secondary peak in the post monsoon months September to November.

TABLE 1. *Productivity of different mangrove areas*

Mangrove areas	Range in the rate of production ($mgC/m^2/$ day)	Seasons of observation
Cochin Estuarine system	725-3200	all seasons
Killai Backwater	125-760	Summer months
Andaman-Nicobar Islands	510-3600	Summer months

Sundararaj and Krishnamurthy (1973) observed a very high production rate of 836.89 $mgC/m^3/hr$ at the mangrove station in Killai backwaters in the summer of 1972. It was nearly 4 fold when compared to the rate observed in the adjacent estuarine waters.

In Andaman and Nicobar islands, the productivity rate of 510 $mgC/m^2/day$ was observed in Kimoi's backwater in Car Nicobar and the high production rate of 3600 $mgC/m^2/day$ was observed at Corbyn's cove.

Thus the rates of production in the observed mangrove areas were moderate to high.

Discussion

In a survey undertaken on the productivity of the prawn culture fields around Cochin, *Gopinathan et al.* (1982) have estimated the production in the seasonal and perennial prawn culture fields as ranging from 650 to 3,800 $mg\ C/m^2/day$. Nair *et al.* (1975) have estimated the total production in the entire estuarine area of Cochin as 100,000 tonnes of Carbon/annum.

For the estuarine system of Cochin, Qasim (1970) has estimated the gross production as ranging from 270-295 $gC/m^2/year$ and an average production equal to 280 gC/m^2. The average net production for 24 hrs has been computed as 124 $gC/m^2/year$ and out of this only 25% is consumed by zooplankton herbivores and the rest is available as surplus food in the form of organic detritus. This will amount to 1000 kg/ha/annum.

Further, during the course of their investigation in the mangrove areas in the Cochin system, the authors estimated that the average quantity of detritus resulting from mangrove litter fall as 1500 kg/ha/annum. Thus the total quantity of basic food available for an omnivorous feeder such as prawn is estimated at 2500 kg/ha/annum in mangrove and mangrove adjacent waters.

Qasim and Easterson (1974) have determined the nutritive value of the estuarine detritus and the energy conversion of a penaeid prawn, *Metapenaeus monoceros* based on laboratory experiments. They found a gross growth efficiency of 10.5 to 35.2% and the assimilation efficiency in the order of 93%.

Taking an average conversion efficiency of 20% for prawns, the detritus production of 2500 kg/ha/annum will sustain a production of 500 kg of prawns ha in the mangrove adjacent prawn fields in the Cochin estuarine system and this figure will go upto 800 kg/ha if we take the conversion efficiency as 30%.

In prawn culture demonstrations carried out in farmers' field by the Central Marine Fisheries Research Institute in Narakkal and other areas near Cochin, it has been observed that prawn seeds stocked at the rate of 40 to 50 thousand/ha has given yields ranging from 123 to 595 kg after a period of about 3 months. The size of seeds varied from 15 to 50 mm at the time of stocking (Anon, 1978). Based on this data and the productivity and conversion efficiency as worked out above it is possible to indicate the optimum stocking densities for a commercially very important cultivable species such as *Penaeus indicus*.

Production rate of basic detrital food	..	2500 kg/ha/annum
Expected production of prawn (*P. indicus*) at 20% conversion efficiency	..	500 kg/ha
No. of harvestable prawn at av. wt. of 12 g each	..	41,667
∴ stocking density of prawn seeds/ha at a survival rate of 80%	..	52,084
Say	..	52,000

In conclusion it may be stated that mangroves in coastal areas and estuaries greatly enrich the productivity of surrounding water bodies. Mangrove creeks and waterways serve as nursery grounds and shelter for a variety of fishes, prawns and molluscs which are commercially important. The productivity of this ecosystem is of particular significance to coastal aquaculture for which national priority is being assigned.

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STUDIES ON THE HYDROGRAPHICAL FEATURES OF VIZHINJAM BAY

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ABSTRACT

Vizhinjam Bay, protected by natural rocky promontories and man-made breakwater offers an ideal ecological niche for the culture of a variety of marine animals. As a part of the ecological study of the Bay, monthly and seasonal variations in rain fall, salinity, temperature, light penetration, pH value, dissolved oxygen content and the availability of major nutrients were investigated. Intense precipitation occurred during October (526.1 mm) from the N. E. monsoon and May (466.5 mm) from the S. W. monsoon. Water temperature was found to be low during the monsoon period. Though salinity variations in general were not wide (27.9 to 36.2‰), the surface salinity exhibited sharp fluctuations in relation to the bottom salinity. Secchi disc readings showed that light penetrates deeper during the pre and post monsoon periods than during the rainy season. Surface water always contained more dissolved oxygen and in May both surface and bottom waters showed very high values (5.1 and 4.6 ml/l respectively). pH value varied from 7.8 to 8.3 in surface and 7.95 to 8.35 in bottom waters. The inorganic nutrients such as reactive phosphate, silicate, nitrite and nitrate exhibited high values during the N. E. monsoon period or by the diminishing stage of the S. W. monsoon i.e., in October or in September. The concentration of all these nutrients has been slightly higher in bottom water than in surface and replenishment of nutrients to the surface by vertical mixing is possible almost throughout the year owing to the shallowness of the Bay (maximum depth is about 11 m). Silicate content varied from 10.5 to 53.8 μg at/l in surface and 11.3 to 57.0 μg at/l in bottom waters. Reactive phosphate values fluctuated between 0.48 and 1.87 μg at/l in surface and 0.67 to 2.1 μg at/l in bottom waters. The recorded range of nitrite-nitrogen content was from 0.07 to 1.32 μg at/l and 0.09 to 1.57 μg at/l respectively in the surface and bottom waters. Nitrate-nitrogen content ranged between 1.86 to 8.05 μg at/l in surface and 2.40 to 9.61 μg at/l in bottom waters. N/P ratios were always found to be low which indicated that if any limitation of primary production occurs in the Bay due to the short supply of nutrients, it must be due to nitrogenous nutrients. In the light of available information, the causes and effects of these hydrographical variations are discussed.

INTRODUCTION

SALINITY, temperature, dissolved oxygen content, pH, light penetration and the availability of nutrients play a major role in regulating the growth, abundance, recruitment and distribution of the fauna and flora in unpolluted coastal marine environments. Fluctuations of these would lead to significant effects in the fertility and primary organic production, thereby affecting the natural food supply and energy flow to the cultivable organisms and to other exploitable trophic levels apart from their direct influence on the capture fisheries. Several earlier studies carried out on the hydrography of various regions of the Arabian Sea and the Bay of Bengal have been primarily directed to find as answer to the fluctuation of fisheries (Sankaranarayanan and Qasim, 1968). Knowledge on the physico-chemical features at certain instances would greatly help to solve specific problems connected with fisheries. Most of the earlier investigations on spatial and temporal variations of these parameters along the coasts of India were concentrated in and around chosen localities. In this paper an attempt is made to deal with and discuss the temporal variations of some major hydrographical parameters and the concentration of inorganic nutrients in the Vizhinjam Bay, south west coast of India, of which almost nothing is known so far though it is an important fishing harbour and an ideal locality for mariculture.

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Physiography of the Bay

Vizhinjam Bay situated in the extreme south west coast of India (Lat. 8°22'N ; Long. 76°56' E) is formed by two rocky promontories, Mathilipuram on the west and Kottapuram on the east which makes the area almost an enclosed water body facilitating fishing and mariculture operations (Fig. 1). Besides, at present, works are in progress to develop the Bay as a fishing harbour by constructing suitable breakwaters. Depth at the station selected for study in the Bay varies from 8 to 9 m. Here commercial culture and harvest of mussels, pearl oysters and experimental culture of lobsters, fishes etc. have been carried out by the CMFRI and State Fisheries Department of Kerala. The protected rocky shores of the Bay with stretches of sand in between and the open rocky shores support rich and varied forms of coastal marine life. The basin is partly rocky and covered over by sediments. There is coral growth over the breakwater which is built by immersing large rocks and concrete blocks. A small channel named

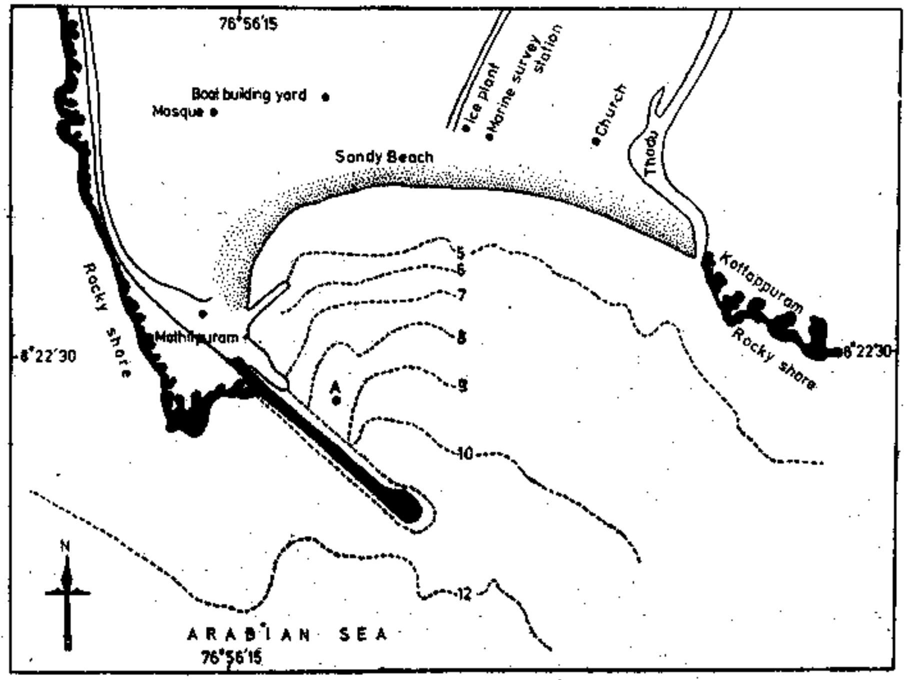

Fig. 1. Vizhinjam Bay showing the location of the station and the breakwater.

Pallichal thodu joins the Bay on the eastern side, but the discharging capacity of it is low and it does not exert any significant influence on the hydrographical features of the Bay. The locality enjoys the fullest benefits of both the south west and the north east monsoons.

Material and Methods

Observations and analyses were carried out at weekly intervals for about 1½ years from December 1976 to May 1978. The values for each week were averaged to monthly means and the data for one year (February 1977 to January 1978) are presented here. Transparency of the water column was measured using a Secchi disc of 20 cm diameter and temperature was read immediately after the collection of surface and bottom water samples. pH of the samples were recorded using an Elico pH meter. Salinity and dissolved oxygen content were estimated titrimetrically adapting the procedures described by Martin (1968), Strickland and Parsons (1965) and Grasshoff (1976). When the analyses were to be delayed, samples for dissolved oxygen after on the spot fixation using Winkler's reagents and those for salinity were stored hermetically in dark. Surface and bottom samples for the analysis of nutrients were, after filteration, stored in polythene bottles for silicate and in glass bottles for others and were frozen until analysis which was carried out almost always within a day after the collection. Phosphate, silicate and nitrite content were estimated following Strickland and Parsons (1965) and Grasshoff (1976). Nitrate content was determined according to Mullin and Riley (1955) as detailed by Barnes (1959). None of the nutrient values were corrected for salt error. Recording of temperature, pH and Secchi disc depth and the collection of water samples were always done between 10 and 11 a.m. The rain fall and atmospheric temperature data were obtained from the Observatory, Trivandrum.

Results

Rain fall

Precipitation was heavy during May to November (Fig. 2). During the period maximum rain fall was in October (526.1 mm) and the next was in May (466.5 mm). The period from December to March had been almost dry and the lowest amount of precipitation was recorded in December (13.7 mm). Between the peaks of the two monsoons a set back could be seen during August-September period.

Temperature

Surface water temperature varied from 24.8°C (September) to 30.5°C (April) and the same in bottom water ranged between 24.8°C (September) and 30.2°C (April). The seasonal fluctuations in water temperature were more pronounced in surface and the variations were found to be slightly less at the bottom. The difference between surface and bottom temperature varied from 0 to 1.8°C. Generally during the period from June to November both surface and bottom waters exhibited low temperatures when the atmospheric temperature also was found to be low (Fig. 2). The highest mean maximum atmospheric temperature was recorded in April (33.1°C) and the lowest mean minimum in January (21.6°C).

Secchi disc visibility

Pre-monsoon months registered higher values of Secchi disc depths and throughout the rainy season low values were encountered. Maximum S.D. visibility depth (462 cm) was noticed in February and the minimum (208 cm) in May (Fig. 3). After the north east monsoon S.D. visibility range showed an increasing trend till it reached the peak value and with the onset of south west monsoon, the transparency of the waters suddenly declined in May. In July also the transparency was found to be very low in Vizhinjam Bay when the Secchi disc was visible upto 212 cm only.

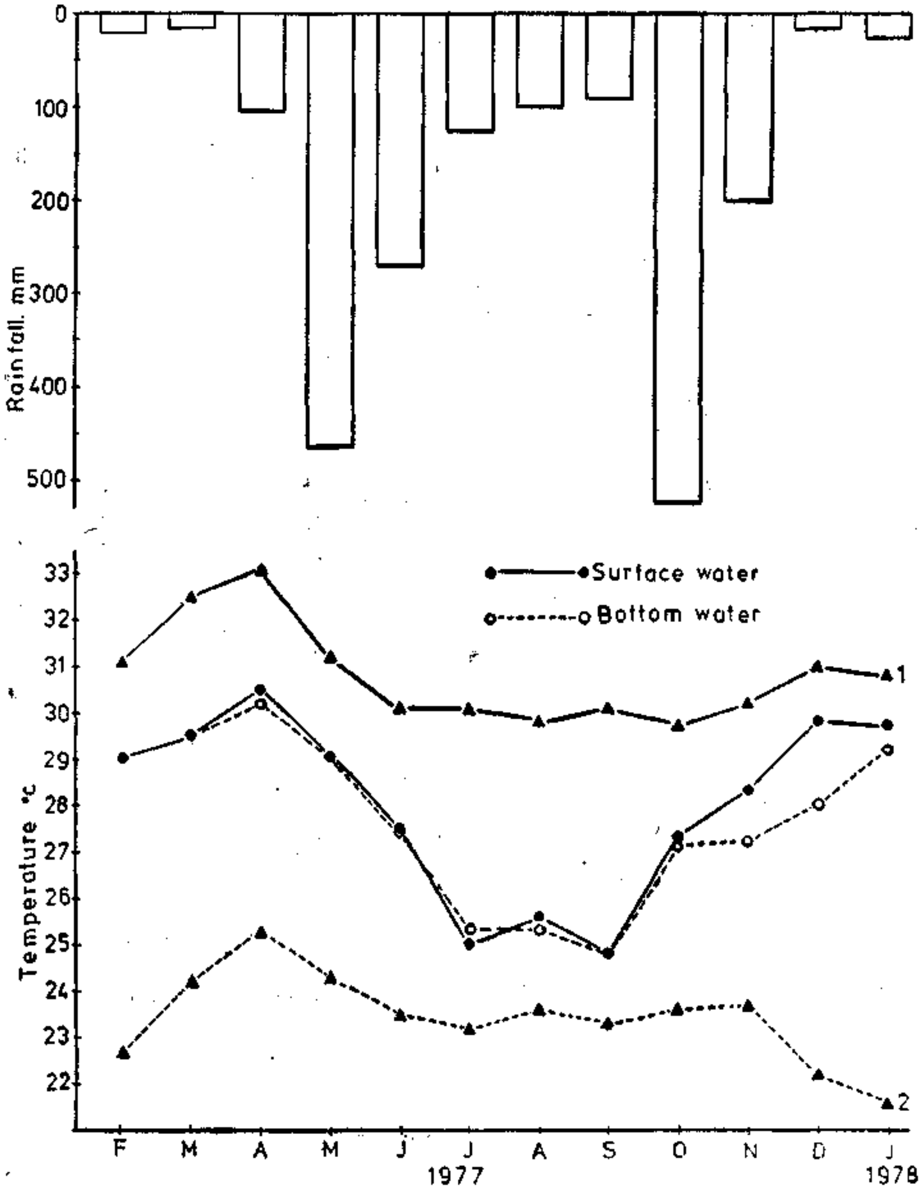

Fig. 2. Monthly variations of rainfall and atmospheric temperature at Trivandrum and water temperature at Vizhinjam Bay. 1 — Mean maximum atmospheric temperature and 2 — mean minimum atmospheric temperature.

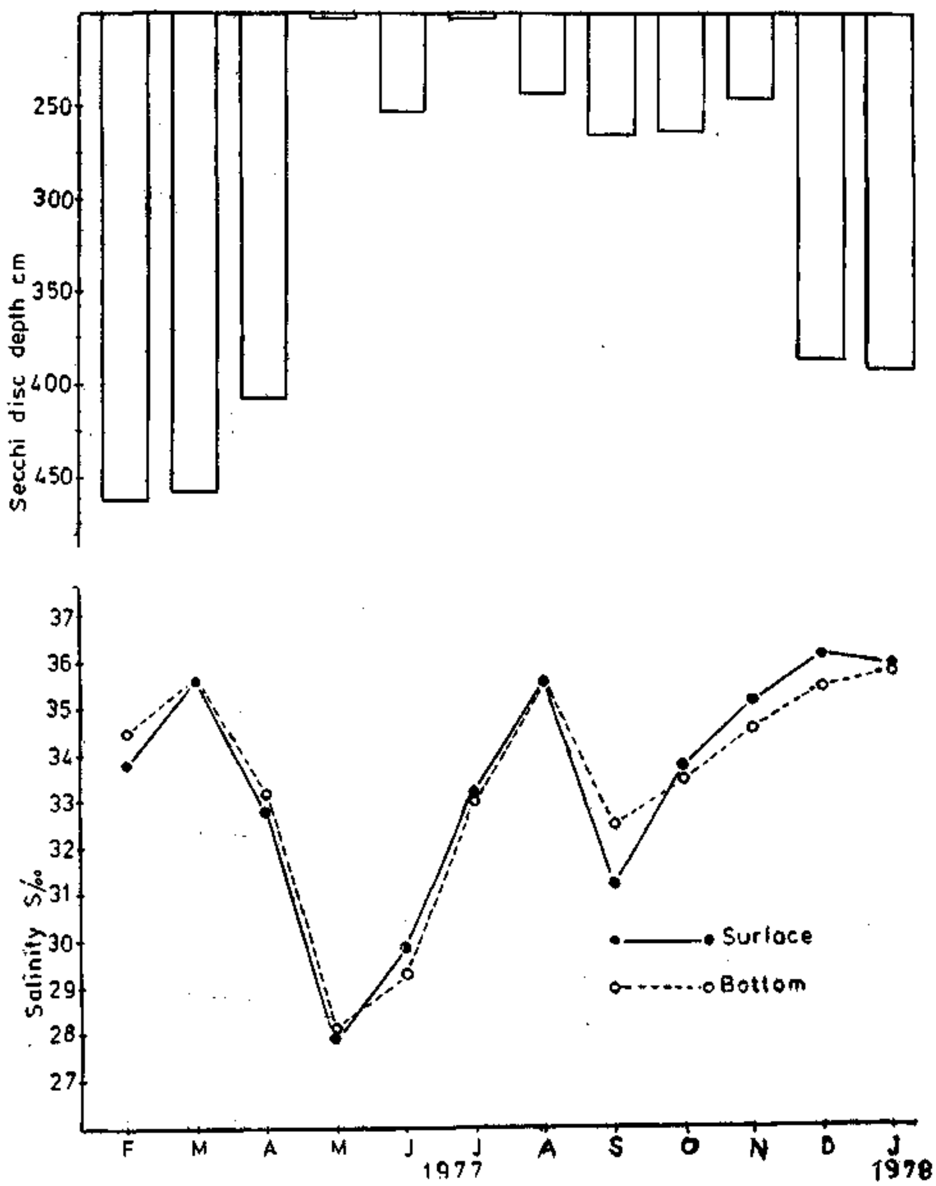

Fig. 3. Variations of Secchi disc visibility depth and salinity.

Salinity

Salinity variations in Vizhinjam Bay were small and at the surface the minimum (27.9‰) was recorded in May and the maximum (36.2‰) in December (Fig. 3). Salinity of the bottom water varied from 28.1‰ in May to 35.8‰ in January. In the case of salinity fluctuations both surface and bottom waters showed almost identical trends and the values were also very close together except in September when a difference of 1.3‰ was recorded. The high salinity which prevailed during the pre-monsoon period was suddenly lowered by the advent of south west monsoon in May, and thereafter it exhibited a rising trend and reached 35.6 and 36.5‰ respectively in surface and bottom waters in August. Again a decline occurred in September and then the values increased slowly.

pH

During the course of the present study, pH of the surface water fluctuated between 7.8 (October) and 8.3 (December and February). Minimum and maximum values recorded in the bottom water were 7.95 (April and June) and 8.35 (February) respectively (Fig. 4). pH of the bottom water remained below that of the surface water from April to July. From August to October surface pH was found to be considerably lower than that of the bottom and the maximum difference of 0.4 occurred in October. In November both surface and bottom waters exhibited same pH value.

Dissolved oxygen content

Generally, higher concentration of dissolved oxygen was noticed during the beginning of south west monsoon and the later half of the pre-monsoon period (Fig. 4). Maximum values recorded at the surface and bottom waters (5.1 ml/l and 4.6 ml/l respectively) occurred in May. Afterwards during the south west monsoon period both surface and bottom waters were found to be poorly oxygenated. Minimum values encountered during the present study at the surface water (3.8 ml/l) and bottom water (3.2 ml/l) were in July and March in the former and July in the later. When the south west monsoon ceased a slight increase in the dissolved oxygen content was discernible. A declining trend occurred during the period of intensive precipitation of the north east monsoon also. Always the bottom water registered lower values than the surface water. Even though a marked seasonal fluctuation in dissolved oxygen content could be observed, the water masses of the Vizhinjam Bay were never found to be poorly oxygenated.

Nutrients

Silicate-silicon

Dissolved silicate content in the water varied from 10.5 μg at/l in January to 53.8 μg at/l in September at the surface and the range recorded at the bottom was from 11.3 μg at/l in January to 57.0 μg at/l in September (Fig. 5). Silicate content was below 20 μg at/l from February to August and during the first two months surface and bottom waters contained almost equal quantities. During the south west monsoon period although higher concentrations of dissolved silicate were expected, only low values were encountered and during the north east monsoon period comparatively higher values and the maximum recorded during the study also were noticed. With the cessation of rains and run off, the silicate content also showed a decline. Except during the first two months, bottom water contained slightly higher dissolved silicate than the surface water.

Inorganic phosphorus

Seasonal distribution of reactive phosphate showed a rough bimodel type of fluctuation exhibiting two peak values during the period of observation. Low concentrations were encountered from December to April. The lowest recorded value in bottom water (0.67

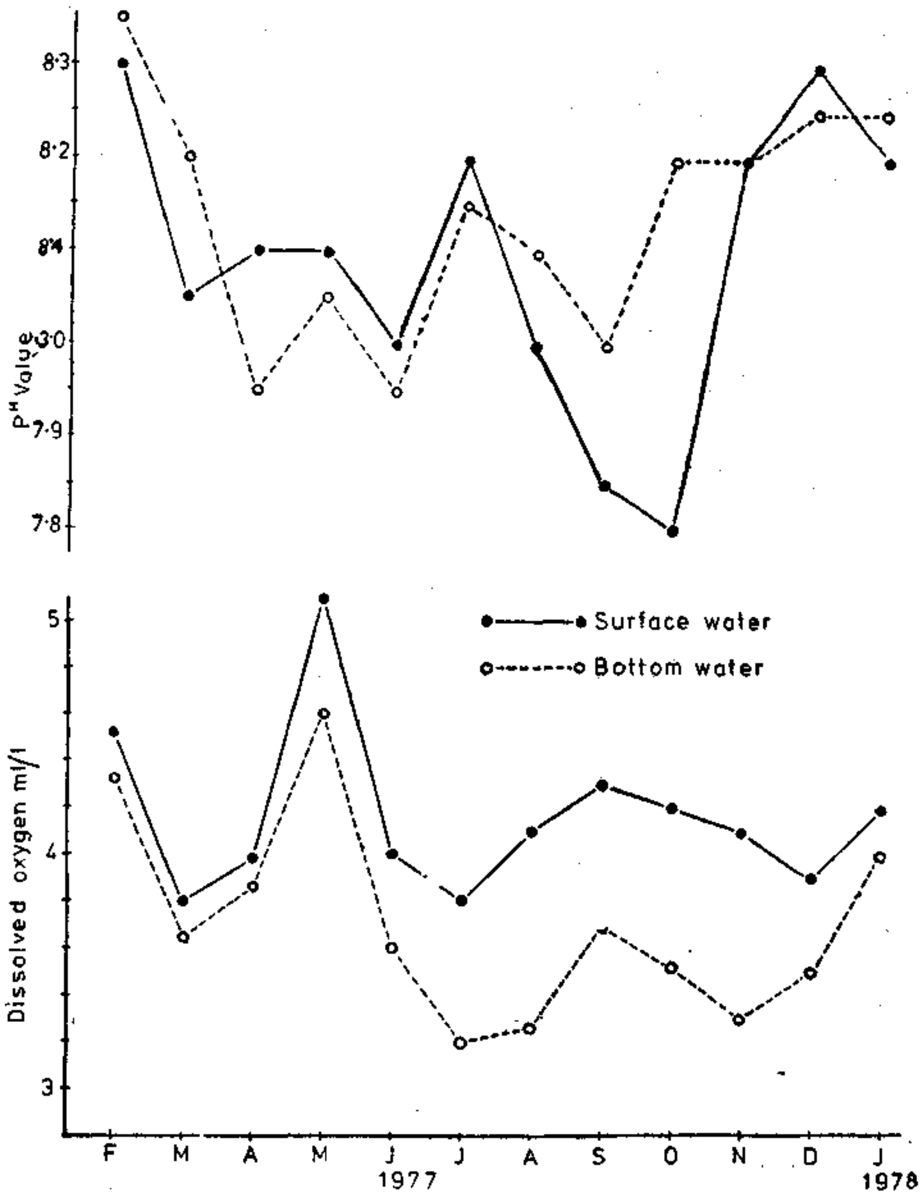

Fig. 4. Variations in the mean monthly values of pH and dissolved oxygen content.

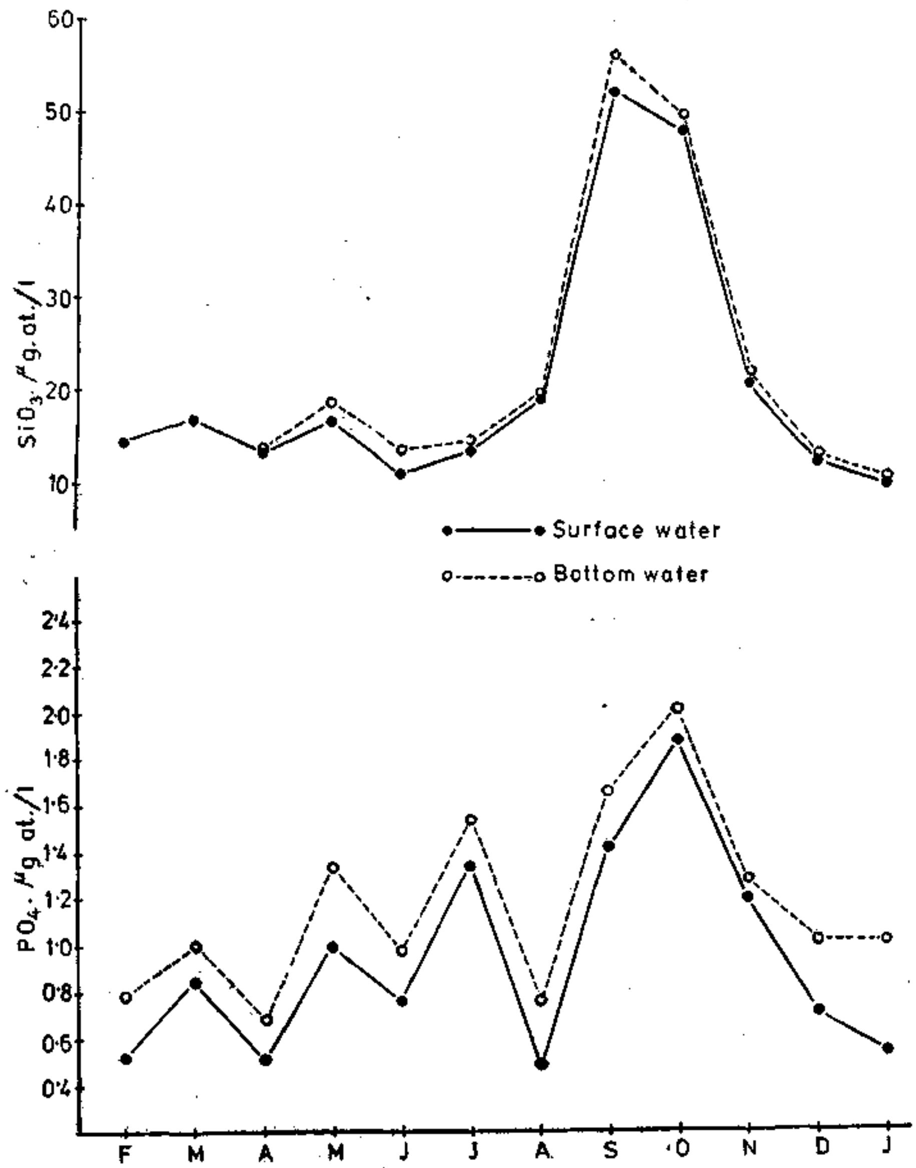

Fig. 5. Monthly average values of silicate-silicon and inorganic phosphate-phosphorus.

μg at/l) occurred in April and the lowest in surface water was in August (Fig. 5). With the advent of south west monsoon, reactive phosphate content rose up in May and it was followed by a decline in June. In July the values reached a secondary peak of 1.33 and 1.53 μg at/l respectively in the surface and bottom waters. A sharp decline occurred in August and afterwards with the onset and intensification of north east monsoon, reactive phosphate content increasedto reach the primary peak values (1.87 and 2.1 μg at/l respectively in the surface and bottom waters) in October which again declined from November onwards. Always reactive phosphate content was found to be comparatively high in the bottom water.

Nitrite-nitrogen

Only very poor concentrations of this nutrient were recorded but it never showed any sign of complete depletion. The variations were between 0.07 (November) and 1.32 μg at/l (September) in surface water (Fig. 6). NO_2-N content varied from 0.09 (November) to 1.57 μg at/l (September) in bottom water. Although NO_2-N content had been little in the surface water from February to June, a slight increase occurred in July. In March bottom water contained appreciable quantity of NO_2-N, though it was very poor at the surface. After the south west monsoon, as in the case of other nutrients NO_2-N content also declined in August and during the north east monsoon period highest concentration of this nutrient prevailed in September and October. The values showed a sharp decline from October to November and those encountered in November were the lowest. Almost always, bottom water contained more NO_2-N than the surface water.

Nitrate-nitrogen

In the surface water the concentration of NO_3-N varied from 1.86 to 8.05 μg at/l respectively in April and September and in the bottom water the values fluctuated between 2.40 (May) and 9.61 μg at/l (September). During the later half of the premonsoon period, very low quantities of NO_3-N were recorded. Always bottom water contained more NO_3-N than the surface water. The concentration of NO_3-N also declined in August as in the case of other nutrients after a slight increase during the south west monsoon period. With the advent of the north east monsoon, values steeply increased in September when the maxima were recorded and comparatively higher NO_3-N content prevailed during October also. It was again found to be low during November and December and afterwards a significant increase occurred only in January.

N/P ratios

NO_3-N/PO_4-P values had been very low during the period of study and it varied from 2.0 in May to 11.85 in January in the surface water. The range observed in the bottom water was from 1.80 in May to 8.23 in January. N : P ratios in surface water did not follow any strict seasonal variations but varied sporadically. The same in the bottom water also did not follow any seasonal sequence or the changes in the surface water.

Discussion

Rain fall data indicates that the north east monsoon in the locality had been more pronounced than in the northern regions of the west coast of India. The division of the year into three distinct seasons, *i.e.* premonsoon (February to May), monsoon (June to September) and postmonsoon (October-January) seems to be slightly different in the southern part of Kerala. The recorded extremes of the water temperature lie within the known limits of its occurrence in tropical seas. Water temperature followed the changes in the same of the atmosphere generally, and similar trends of temperature fluctuations in the nearshore

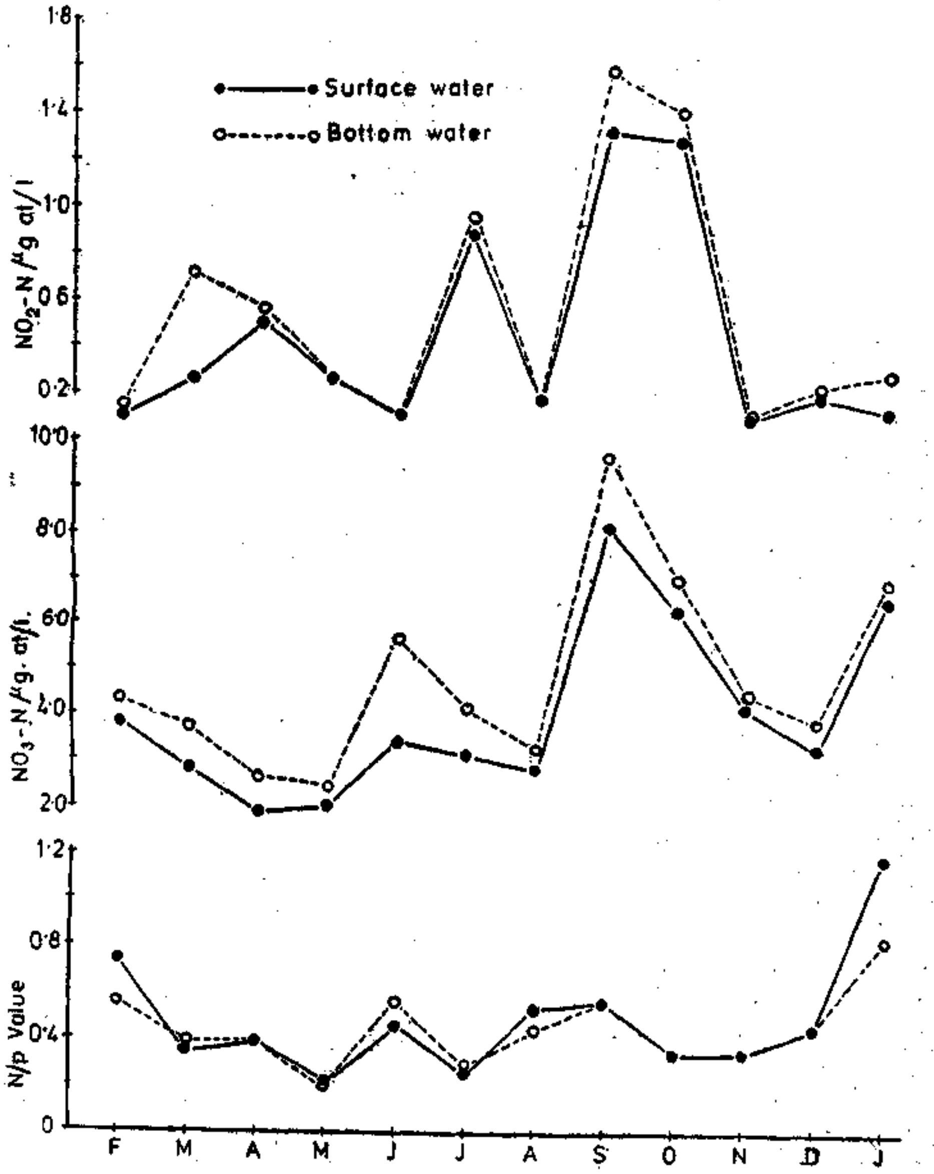

Fig. 6. Monthly variations of nitrite-nitrogen, nitrate-nitrogen and N ; P ratio.

waters of the west coast of India have already been reported (Suresh *et al.*, 1978 ; Noble, 1968 ; Varma *et al.*, 1975). Low water temperature recorded from June to October would be due to the comparatively cooler atmosphere and the cooling effect of rain fall. Besides, upwelling of cold sub-surface sea water and intrusion of it into estuaries and bays have been observed throughout the west coast of India during the monsoon season, however with varying intensities and period of occurrence (Sankaranarayanan and Jayaraman, 1972 ; Suresh and Reddy, 1978 ; Banse, 1959 ; Ramamirtham and Jayaraman, 1963). Haridas *et al.* (1973) also observed a slight rise in temperature in August at Cochin backwaters as recorded in the present study. Under the observed dynamics of temperature in the surface and bottom waters at Vizhinjam Bay, there is no possibility for the development of a thermocline during any season of the year.

Transparency of the water and the penetration of light into the water column on which the ultimate process of carbon fixation depends have been governed by the combined effects of meteorological, physical and biological parameters. It is directly related to the quantity of solar radiation that reaches the water surface. Calmness of the water, low turbidity and clear sky could be attributed to the high Secchi disc visibility readings recorded during the premonsoon period. The presence of less turbid water masses during the period would be due to the lack of land drainage with suspended sediment load. However, differences in the optical quality of the water mass, plankton biomass and sediments also would influence the extinction coefficients of light (Reddy *et al.*, 1979). Kaliyamurthy (1973) has observed low attenuation coefficients during premonsoon, high values during monsoon and progressive increase in the Secchi disc visibility with increasing depth at Pulicat Lake. Cochin backwaters generally receive maximum solar radiation from January-April (Qasim, 1973). Apart from land drainage with enormous quantities of suspended sediment load, monsoonal winds which stir up the bottom, cloudiness of the sky, possible upwelling during the time, greater agitation of the water masses and luxuriant growth of plankton during the diminishing stages of monsoon would add to the causes of low transparency and high turbidity during the monsoon period. An inverse relationship between plankton biomass and the visual range of Secchi disc has been reported from the Bay of Bengal (Rao, 1957). The role of dissolved organic matter and yellow substance also could not be ruled out since they absorb much light and cause rapid attenuation. In some localities in the north west Indian coastal waters, turbidity limits the primary production (Radhakrishna *et al.*, 1978). However, in Vizhinjam Bay very low Secchi disc depths that could adversely affect the primary production were never encountered.

As there is no large river emptying into the Vizhinjam Bay, salinity fluctuations mainly depend on rain fall and land drainage. Both the minimum and maximum values recorded are exceeded by the already reported extreme values from the Arabian Sea (Noble, 1968 ; Annigeri, 1968, 1972 ; Jayaraman *et al.*, 1961). Coinciding with high temperature, the salinity also was found to be high. Higher salinity recorded during the dry seasons could be attributed to the evaporation of water resulting from excessive solar radiation and the lack of land drainage. Comparatively lower salinity values recorded during the monsoon months were due to the precipitation and resultant mixing of fresh water with the sea water. The increased salinity during August would be due to intrusion of high saline offshore subsurface water. Similar pattern of seasonal variation in salinity was observed in North Kanara coastal waters also (Noble, 1968). The absence of marked vertical gradients in salinity and temperature at Vizhinjam Bay might be indicative of the almost homogeneous nature of the water column which would never be of any hindrance to vertical mixing and the replenishment of nutrients to the euphotic zone.

Variation in pH is governed by a number of factors such as photosynthetic release of oxygen and absorption of CO_2, respiratory processes of animals and plants, monsoonal precipitation, oxidative processes and the resultant dynamics of dissolved oxygen content etc. Noble (1968) recorded pH values ranging from 7.3 to 8.05 in the surface water of the Kanara coast. The role of dissolved oxygen and CO_2 in regulating the pH of natural waters has been emphasised by Sankaranarayanan (1973) by attributing the photosynthetic release of oxygen to the cause of high pH during day time and the respiratory release of CO_2 to the cause of low pH during night.

Higher concentration of dissolved oxygen recorded during the premonsoon period might be due to the photosynthetic release of oxygen and the maximum values observed in May would have been caused by the agitation of water during the dense south west monsoon rains and photosynthetic release. Bhargava *et al.* (1973) also observed high dissolved oxygen content along the Panaji-Bombay coast during April and May. Generally during the summer months, phytoplankton biomass and production have been high almost throughout the Indian coasts (Qasim, 1977; Bhargava *et al.*, 1973; Vijayalakshmi and Venugopalan, 1975). Agitation of the water masses and the resultant solubility of atmospheric oxygen could be the reason for the high dissolved oxygen content observed throughout the year in Vizhinjam Bay. The slightly lower dissolved oxygen content observed during June-July and the low values recorded throughout in the bottom water were due to the utilization of it for the decomposition of organic matter brought to the Bay along with land drainage. Upwelling of poorly oxygenated water has also been reported to occur along the west coast of India during the monsoon season (Ramamirtham and Rao, 1973; Sankaranarayanan and Qasim, 1969). The productivity of coral zooxanthellae also would exert significant influence on the dissolved oxygen content and pH in Vizhinjam Bay. Verwey (1931) found that the release of oxygen by coral zooxanthellae is nearly two to five times more than the consumption of it by the corals and reef communities in shallow waters.

Major sources of silicates to Vizhinjam Bay were from land drainage and solublization of clay minerals and diatom frustules which contain much solidified silicates. It has been found that the nutrient contents were often considerably higher in fresh water than the corresponding amounts in marine environments and the mixing of fresh water with sea water may lead to about 40% removal of dissolved silicon present in the former (Liss, 1976). In Cochin Harbour, Joseph (1974) observed low silicate content during the premonsoon, high content during the monsoon and intermediate values during the post monsoon. The low values encountered during the south west monsoon period and the sudden decline noted after the north east monsoon seemed to be due to the removal by precipitation as insoluble silicate minerals and utilization by phytoplankton. Purushothaman and Venugopalan (1972) reported that much of the dissolved silicates in water is removed by inorganic precipitation and biological uptake. Silicon replenishment by the solublization of silicate minerals and diatom frustules might have been responsible for the higher concentration of this nutrient apparent in the bottom water. Silicate dissolving bacteria which commonly occur in coastal and estuarine environments (Purushothaman *et al.*, 1974, 1975) also would play significant role in the cycle of this nutrient.

Phosphorus in combination with nitrogen is the most important nutrient essential for the growth of phytoplankton and primary production. Depending on the quantity present in waters, phosphorus could limit the production and also cause eutrophication leading to phytoplankton blooms and subsequent deliterious effects on the animal life of the locality. In Vizhinjam Bay, the supply of reactive phosphate is almost steady showing only minor ups and downs in the concentration. Discharge of land drainage into the Bay seems to be a source of contribution since both during the south west and north east monsoon periods high values of dissolved phosphate content were encountered. Oxidation of organic matter is also a source evidenced by the higher concentrations recorded in the bottom water. Almost similar types of seasonal fluctuations in reactive phosphate content have been observed in many localities (Sankaranarayanan and Qasim, 1969; Pillai *et al.*, 1975). Primary production and the resultant removal of dissolved inorganic phosphate is the major source of biological removal of reactive phosphate (Sankaranarayanan, 1973; Rajendran and Venugopalan, 1973). The absorption by macro algae in this rocky coast may also considerably reduce the reactive phosphate level. Mc Roy and Barsdate (1970) have found that some algae absorb PO_4 through leaves and roots, utilizing PO_4 both from the sediments and overlying water. It has been reported that reactive phosphate content above approximately 3 μg-at/l will be a sign leading to eutrophication (Ketchum, 1967). Such critically higher values or very low values which may limit the primary production were never encountered in Vizhinjam Bay. Phosphate regenerative activity of the muds (Reddy and Sankaranarayanan, 1972) and the exchange of phosphorus between sediments and overlying water (Balasubramanian, 1961; Pomeroy *et al.*, 1965) might have been responsible for the presence of considerable quantities of dissolved phosphate throughout the year in the Bay. The activities of phosphate solublizing bacteria may also contribute much to the phosphate budget in natural waters (Ayyakkannu and Chandramohan, 1970, 1971).

Monsoon rains and the resultant land drainage have profound influence on the seasonal cycle of nitrite and nitrate in Vizhinjam Bay. Oxidation of organic matter, land drainage during the monsoon season, nitrogen fixation by bacteria and blue green algae, excretion by plankton and nekton *etc.* are the chief sources of these nutrients. Following Sankaranarayanan and Qasim (1969) higher values of NO_3-N recorded during the monsoon months could be attributed to land drainage. Sudden and steep fluctuations in the concentration of these two nutrients seem to be due to rapid utilization soon after replenishment. Similar trends in the seasonal variations of NO_3-N content have been reported from Cochin backwaters (Qasim, 1973). Very low values of NO_2-N were observed in Cochin backwaters almost throughout the year except a prominent peak in September and it has been assumed that nitrate reduction takes place or there is arrested oxidation of organic matter in regions and periods of nitrate maxima (Joseph, 1974). The process of denitrification is not likely in Vizhinjam Bay, since anoxic or very poorly oxygenated waters were never encountered. Very low values of the premonsoon period would be due to biological uptake. The existence of nitrogen fixing bacteria in marine environments (Laksmanaperumalswamy *et al.*, 1975) and the ability of several groups of other microbes like blue green algae to fix atmospheric nitrogen in aquatic environments (Riley, 1971) have been reported. Menzel and Spaeth (1962) reported that ammonia content increases considerably with rain fall and the oxidation of it subsequently to NO_2 and NO_3 may increase the concentration of NO_2-N and NO_3-N during the monsoon periods. The process of nitrification may also be facilitated by enzymes present in marine sediments which are capable of releasing ammonia (Dharmaraj *et al.*, 1977) which in turn could be oxidised to NO_2 and NO_3. Assimilation of NO_3-N by marine phytoplankton was often found to be accompanied by considerable extracellular production of NO_2-N (Vaccaro and Ryther, 1960) which would account for the presence of NO_2-N throughout the year in Vizhinjam Bay, though it is unstable.

Low N/P values indicate that there has been comparatively low NO_3-N content than PO_4-P almost throughout the year. The ratios are considerably lower than those by which they are normally absorbed by phytoplankton and in which they occur in oceanic waters at all depths *i.e.* approximately 15 : 1 (Riley, 1971). Such low ratios have already been reported from several coastal and estuarine localities of India (Bhattathiri *et al.*, 1976 ; Sankaranarayanan and Qasim, 1969). Purushothaman and Bhatnagar (1976) observed N/P values ranging from 1 to 12 with minimum values coinciding with maximum production and vice versa. Based on the observed low values of N/P, it is presumed that if any nutrient limits the primary productivity in Vizhinjam Bay it must be nitrogen. Ketchum (1967) concluded that in waters with low N : P ratio, phosphate will generally be present in sufficient quantities and nitrogen could be the limiting nutrient. Wide and irregular fluctuations of N/P values both in the surface and bottom waters suggest that the replenishments of NO_3-N and PO_4-P are not in a constant ratio even though these nutrients are biologically utilised in an almost constant ratio.

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PHYSICO-CHEMICAL NATURE AND BIOMASS PRODUCTION OF NEWLY CONSTRUCTED BRACKISHWATER IMPOUNDMENTS (NONA GHERI) IN THE LOWER SUNDERBANS

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ABSTRACT

Four identical, newly constructed brackishwater impoundments in the Bakkhali fish farm in Lower Sunderbans, were studied as to their natural variation in physico-chemical characteristics of soil and water, in relation to salinity and total biomass production, for three years since their inception. The bed soil in general was having neutral pH (6.6—7.3), high P_2O_5 (13.8—30.6) mg/100 g), low available nitrogen (4.0—8.6 mg/100 g) and organic carbon (0.36—0.60%). The soil salinity gradually reduced from 1.30 to 0.12‰ during the three years while water salinity fluctuated between 2.40‰ and 38.70‰ with moderate concentration of dissolved nitrogen and phosphorus. The dissolved organic nitrogen content was estimated to be very low compared to inorganic one. The total biomass production varied between 495 and 1320 mg/sq. m. With the increase of salinity a marked rise in ammoniacal nitrogen was noticed and this resulted in higher production of benthos and also the total biomass. Water salinity above 16‰ was found to be desirable in maintaining high concentration of dissolved nitrogen in the eco-system and for higher biomass production.

INTRODUCTION

THE TYPICAL topography of deltaic West Bengal gives rise to innumerable swampy and marshy mud-flats in between the net work of saline creeks which experience regular inundation with the diurnal tidal periodicity. The brackish water impoundments developed in enclosing these mud-flats with earthen dykes for fish and prawn culture are locally known as '*Nona Gheri*' or '*Bheri*'. In spite of their lucrative output Pakrasi (1965) reported that about 200 *bheris* only are in existence occupying a fraction of the 0.4 million ha culturable area in the lower Sunderbans. The nature of soil and water is vital for the growth of benthic algae (Pillay *et al.*, 1962) and on this depends the productivity of brackishwater impoundments (Schuster, 1952; Pillay, 1954). A detail information on the physico-chemical nature of *bheri* soil and water is essential. Banerjee and Banerjee (1975) and Chattopadhyay (1978) have given some account on the nature of brackish-water pond soil and water. This investigation is on the soil and water characteristics of four identical brackishwater impoundments and their biomass production under fluctuating soil and water salinity carried out in Bakkhali Fish Farm of this Institute in lower Sunderbans.

The authors express their deep gratitude to Dr. A. V. Natarajan, Director of the Institute for kindly allowing to present this paper at the Coastal Aquaculture Symposium.

MATERIAL AND METHODS

Observations were made in four 1 ha identical shallow impoundments situated on both sides of a common feeder canal originated from a creek. The impoundment beds were having one in 50 slope on the side away from the feeder canal and the average annual water depth was maintained between 0.5 and 1 m. The study was made from the inception *i.e.* 1970 to 1972. Water samples were analysed fortnightly following APHA (1965) and representative soil samples were analysed every month following Piper (1960). Monthly sampling for biomass was also done.

Biomass was determined with a specially designed 25 × 25 cm × 1 m hollow cube made of thin iron sheet and open at both ends. This used to be vertically inserted into the pond bed upto a depth of 10 cm. The water therein was collected and filtered through bolting silk and bottom mud sieved through No. 40 sieve. The entire collection from representative samples was kept under 600°C in a muffle furnace for 30 minutes and the loss on ignition had been considered for the biomass.

Results and Discussion

The bed of these impoundments were sandy loamy in texture, but gradually with the deposition of silt the physical composition changed accordingly. The soil pH varied between 6.8 and 7.5, *i.e.* almost neutral in reaction. Chattopadhyay and Mandal (MSS) reported that the brackishwater pond soils were slightly alkaline (pH 7.9- 8.4), but as per Redman and Pattrick (1965), on submergence the soil pH tend to shift to near neutral. The water pH was towards the alkaline range (7.5-8.5).

Banerjee *et al.* (1976) found that the shallow impoundments in brackishwater zone of lower Sunderbans markedly lost both water and soil salinity during a retention period of about six months. In this observation also with the tidal ingress the water salinity used to increase sometimes upto 34.8‰, but at the end of four months it came down7.2‰. In soil the decreasing trend was more pronounced.

In general, Sunderbans soil is rich in available phosphate and on inundation on the bed as well as the supernatant water maintain high phosphate concentration. Mandal (1961) found that on water logging the available phosphate in non-saline soil increases. Again Chattopadhyay and Ghosh (1976) reported that with the increase in salinity the concentration of available phosphate declined probably due to the increase of calcium ions donated by the highly saline water. During this prolonged observation neither such correlation could be established either in soil or in water media. The concentration of soil available phosphate on average fluctuated between 18.0 mg P_2O_5/ 100 g and the dissolved phosphate between 0.07 and 0.30 mg/l. It is evident from Fig. 2 that higher values of available phosphate were recorded mostly in the soil salinity range 0.1 to 0.45‰. In between the soil salinity 0.5 and 1.0‰ the phosphate level mostly varied between 9.0 and 14.0 mg/100 g. At salinity higher than 1‰ the soil phosphorus followed no definite trend. Fig. 1 depicts that at the water salinity range 20.1 to 34.8‰ the dissolved phosphate fluctuated between 0.13 and 0.20 mg/l and at the ranges 11.5 to 18.0‰ and 3.3 to 9.9‰ the respective phosphate ranged 0.10 to 0.30 mg/l and 0.10 to 0.30 mg/l.

Nitrogen is the vital limiting factor in the aquatic biomass production and its presence always in optimum concentration is highly desirable. These impoundments althrough maintained a low level of available nitrogen in the soil and the average range was 4.4 to 8.4 mg/100 g (Fig. 3). In contrast the dissolved nitrate concentration was always present in fairly high level and mostly fluctuated between 0.15 and 0.35 mg/l in a wide variation of salinity (5.0to 20.0‰) (Fig. 1). Mandal (1962) obtained maximum release of nitrate within the salinity range 10 to 20‰ under controlled condition. The high nitrate level in spite of the low range of available nitrogen and wider fluctuation of salinity might be due to the fact that with the ingress of tidal water nitrogen both in organic and inorganic is being added in the eco-system and also the microbes which are avoided in the controlled condition play an important role in the supply of oxidised nitrogen.

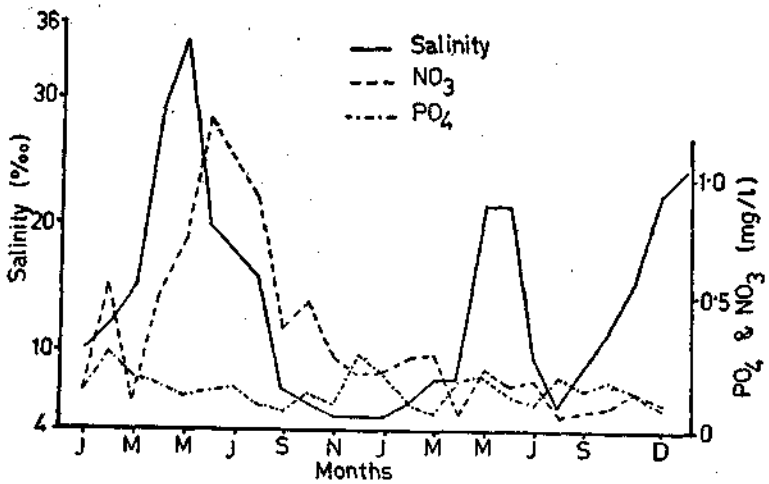

Fig. 1. Salinity, phosphate and nitrate in water in different months (Average of four impoundments).

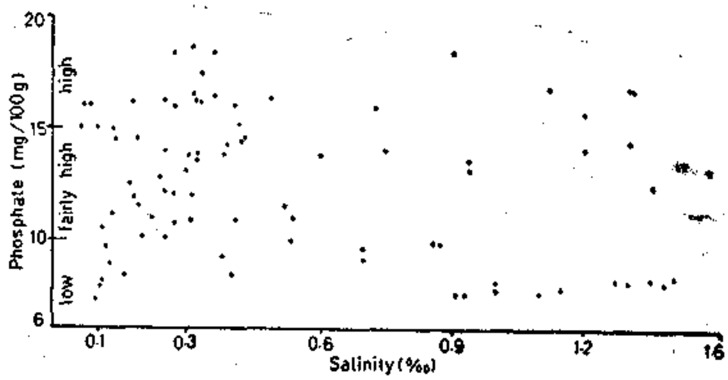

Fig. 2. P_2O_5 concentration in soil at different soil salinities.

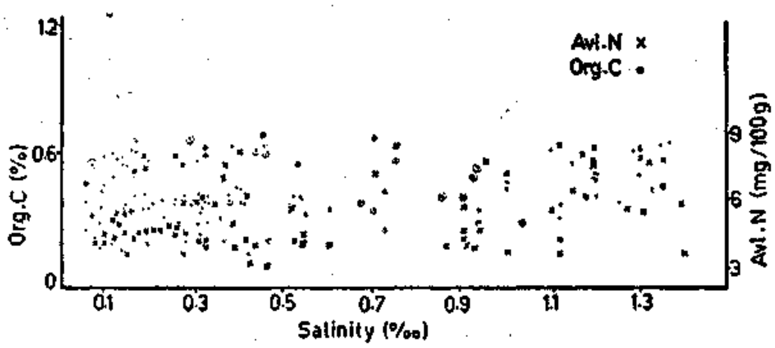

Fig. 3. Nitrogen concentration and organic carbon in soil at different soil salinities.

Major portion of the nitrogen consumed in any eco-system comes from the organic source and accordingly a considerable amount of reserve organic matter should be criteria of any productive ecosystem. The impoundments studied were having low organic matter content. The organic carbon level was on average between 0.35 and 0.58‰. Fig. 3 indicates that even at highest salinity level, where the mineralisation is considered to be minimum the organic carbon value is 0.65‰, and at lowest salinity level the value is 0.32‰. The corresponding available nitrogen as plotted together fail to indicate any definite trend of inter relationship.

Total biomass production is a major index of the productivity of any water body. The highest average of biomass production recorded was 1320 mg/sq. m and on average the production was between 520 and 737 mg/sq.m. The total plankton counts, phyto and zoo together varied between 300 and 1100 units/l. The algal mats contributed the major share of the total production.

Considering all these parameters it can be commented upon that the abrupt rise and fall of the salt concentration of soil and water, prohibits the stabilisation of the eco-system. The composition as well as the cycle of the micro-organism might be greatly affected by the sudden change in the electrical conductance. The organic matter reserve in the system is very low and should be fortified with suitable organic manure. Proper economic measures should be adopted to increase the frequency of tidal ingress. The addition of highly saline water may partly reduce the sudden lowering of the salinity level and may bring stabilisation in the system.

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A SIMPLE BIOLOGICAL FILTER FOR RECIRCULATING SEAWATER SYSTEMS

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ABSTRACT

A biological filter using air lifts for recirculating seawater through a bed of gravel has been developed at the Narakkal Prawn Culture Laboratory of the CMFRI for rearing marine animals. The details of construction are given in this paper. The effectiveness of this recirculating system is discussed.

INTRODUCTION

IN CLOSED system aquaculture of crustaceans and fishes, ammonia which is their main excretory product accumulates in the water and, if not removed, proves toxic to the animals. Even at sublethal concentrations, ammonia has been shown to retard the growth of the animals (Wickins, 1976). Hence it is imperative that the ammonia should be removed from the medium, if the animals are to grow normally. Various types of biological filters have been used to convert the toxic ammonia into harmless nitrates by bacterial action (Spotte, 1970). The principle is well known. When the water is passed through a layer of gravel on which nitrifying bacteria normally settle and grow, the ammonia is oxidised to nitrites by bacteria belonging to the genus *Nitrosomonas* and the nitrites are further oxidised to nitrates by the bacteria of the genus *Nitrobacter* (Wickins, 1976). An inexpensive submerged biological filter developed at the Narakkal Prawn Culture Laboratory of the Central Marine Fisheries Research Institute, to maintain brood-stocks of penaeid prawns in recirculated seawater is described here.

The authors are grateful to Dr. E. G. Silas, Director, CMFRI, Cochin for encouragement and facilities provided and to Dr. M. J. George, Mr. K. H. Mohamed and Dr. P. V. Rao for going through the manuscript and offering valuable suggestions.

DESCRIPTION OF FILTER

The filter consists of a rectangular wooden frame 136 cm long, 90 cm wide and 20 cm high, divided into two compartments by a horizontal wooden partition made of reepers set 25 cms apart (Plate I). The upper open compartment is 5 cm deep filled with gravel chips 0.5 to 1.0 cm in size. The lower compartment is closed when the frame rests on the bottom of the pool. A beading of split polythene tubing is given to the lower margin of the frame to make the bottom water tight. The horizontal wooden partition is covered with a velon screen having 64 meshes to a sq. cm to prevent the gravel chips from falling into the lower compartment. Water from the lower compartment is airlifted to the surface through 4 rigid PVC stand-pipes, 85 cms in length and 5 cm in outer diameter, kept in round holes in the horizontal partition. To replace the water that is airlifted, water in the tank passes downwards through the gravel layer and thus a recirculation of water through the gravel is set up. Ammonia from the water is oxidised by the nitrifying bacteria growing on the gravel substrate, when the water circulates through the filter. The aerating stones that are kept in the airlift, apart from providing the motive force for recirculating the water, also keep the water well oxygenated. Broken pieces of oyster shells are kept mixed with the gravel to stabilize the pH. The surface area of each filter unit is 1.22 sq. metres. A number of filter units can be kept side by side to increase the surface area according to the size of the pools. In our broodstock tanks which are 3.6 metres in diameter we use 4 filter units.

Experimental Evidence of Control of Ammonia Levels

In order to verify whether the filter actually removes ammonia from the water, the following experiments were conducted. Two 1.8 m diameter plastic lined pools containing 1600 litres of seawater were set up. One of the pools contained one unit of biological filter which had previously been conditioned in seawater for 15 days. The other was without a filter but had 4 aerating stones. Each pool contained 8 specimens of *Penaeus indicus* each weighing about 12 gm. The animals were fed with fresh clam meat and the uneaten food and excreta were removed by siphoning every day. The ammonia excreted by the prawns provided the ammonia source. The ammonia concentration was monitored daily for 13 days by the improved phenyl hypochlorite method of Harwood and Kuhn (1970). The initial concentration of ammonia was 0.018 mg NH_4/litre in both the pools. The ammonia level remained more or less stationary in the pool with the biological

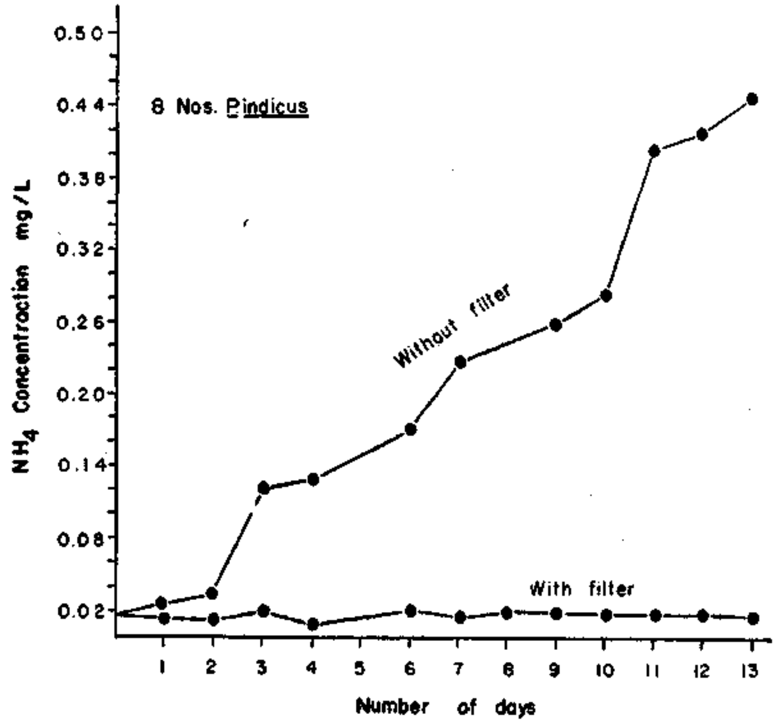

Fig. 1. Ammonia concentration in pools with and without biological filter. 8 specimens of *P. indicus* were kept in each pool.

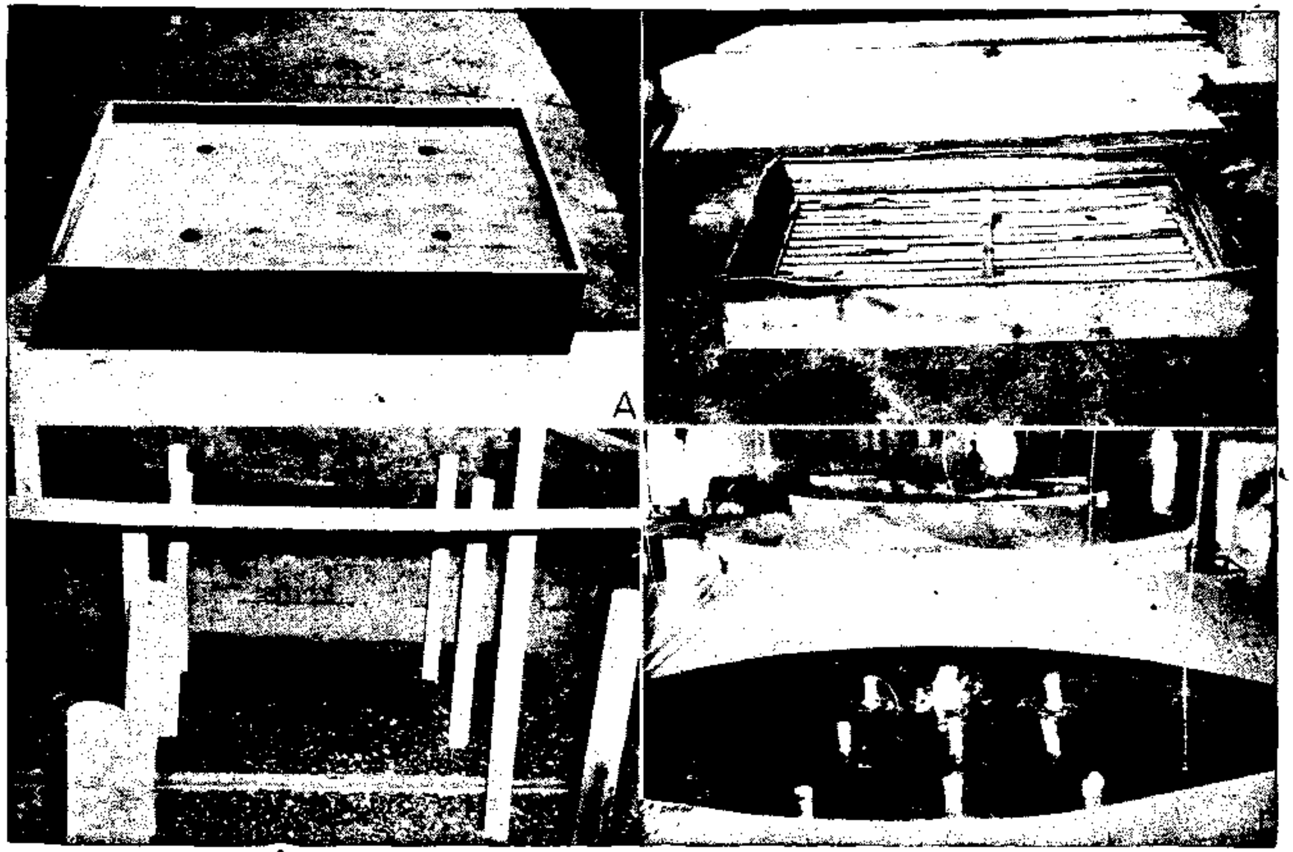

PLATE I. Details of biological filter. A. Dorsal view of wooden frame of filter with velon screen covering the reapers, B. Ventral view of wooden frame of filter showing reapers, C. Biological filter with gravel and PVC stand pipes in position and D. Biological filter installed in the maturation pool.

filter throughout the experimental period, while in the pool without the filter the ammonia level increased steeply due to the accumulation of the ammonia excreted by the prawns and reached a concentration of 0.44 mg NH_4/litre on the 13th day (Fig. 1). The experiment was repeated with 4 *P. monodon* (av. weight 80 gm) as the ammonia source and similar results were obtained (Fig. 2).

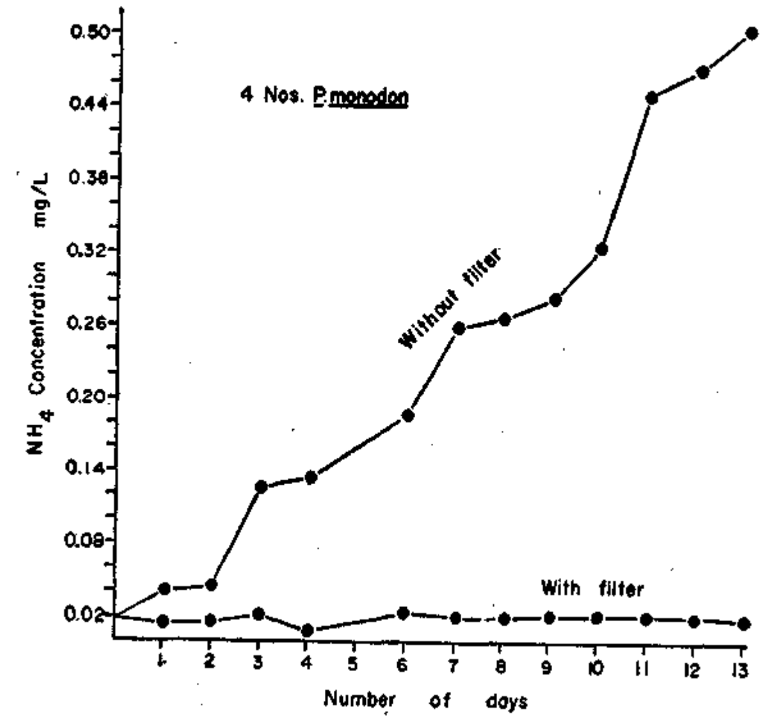

Fig. 2. Ammonia concentration in pools with and without biological filters. 4 specimens of *P. monodon* were kept in each pool.

Conclusion

The above experiments conclusively proved that the ammonia excreted by the animals was effectively removed by the biological filter. However, the pH of the seawater declined from 8.1 at the start of the experiment to 7.6 towards the end. It is therefore advisable to replace at least 50% of the water in the pool every week with fresh seawater.

Based on these results it was estimated that in the 3.6 m dia. broodstock tanks at the Prawn Culture Laboratory, Narakkal, where 4 units of the biological filter were used, a minimum of 32 *P. indicus* or 16 *P. monodon* could be safely kept. However, the optimum 'carrying capacity' of the filters can be assessed only on the basis of further experiments where the ammonia levels should be monitored daily in filter-fitted tanks stocked with different numbers of animals.

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A COMPARATIVE STUDY ON THE NATURE AND PROPERTIES OF SOME BRACKISHWATER AND NEARBY FRESHWATER FISH POND SOILS

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ABSTRACT

Nature and properties of six brackishwater and six nearby freshwater fish pond soils representing different areas in coastal West Bengal were studied in order to understand how the characters of brackishwater pond soils differ from those of freshwater ponds. The study revealed brackishwater and freshwater pond soils to have almost similar pH ranges with average values of 7.70 and 7.50 respectively. Highly saline conditions in brackishwater ponds (water salinity 6.10 to 23.80 ppt) resulted in higher electrical conductivity values of the soils (average 6.90 mmhos/cm) over those of freshwater ponds (average 3.50 mmhos/cm). Organic carbon content were relatively lower (average 0.27%) and calcium carbonate values were slightly higher (average 2.90%) in brackishwater pond soils than in freshwater ponds (average 0.42% and 2.30% respectively). Freshwater pond soils contained comparatively higher amount of available nitrogen (average 13.60 mg/100g soil) and lower amount of available phosphorus (average 1.60 mg/100 g soil) than brackishwater pond soils with corresponding average values of 10.40 and 2.60 mg/100 g soil.

INTRODUCTION

THE PRODUCTIVITY of the ponds was directly related to the nutrient status of the bottom mud (Pillay *et al.*, 1962). Hickling (1971) also emphasized the importance of bottom soil in maintaining the fertility of brackishwater fish ponds since benthic algae, which form the main fish food organisms in such ponds, grow on the pond soil base. Importance of the nature and properties of brackishwater fish pond soils on productivity of the ponds has also been described by workers like Tang and Chen (1967), Djajadiredja and Poernomo (1972) and others.

The physico-chemical properties of the soils of brackishwater fish ponds differ widely from those of freshwater ponds mostly due to remaining submerged under highly saline tidal water. Mandal (1962) characterised such soils texturally by high clay content, chemically by high percentage of exchangeable sodium and alkaline reaction and physically by extremely low permeability. Although some work has been done to identify the nature and properties of brackishwater fish pond soils in India (Chattopadhyay, 1978), information showing how the properties of such soils differ from those of freshwater ponds in the same region are still very meagre. Therefore, in the present investigation, it was decided to make a comparative study on the nature and properties of some brackishwater and nearby freshwater fish pond soils in coastal areas of West Bengal, with the objective of knowing whether there is need for any differential management practice for improving the fertility of brackishwater pond soils.

Authors are grateful to Dr. A. V. Natarajan, Director, Central Inland Fisheries Research

Institute, Barrackpore for his keen interest in the study and to Shri K. K. Ghosh, Officer-in-Charge, Estuarine Section, Central Inland Fisheries Research Institute, Barrackpore for critically going through the manuscript and suggesting improvements.

MATERIAL AND METHODS

Soil samples were collected from six different locations covering the main areas of concentration of brackishwater fish farms in coastal West Bengal (Fig. 1). In each location, samples were collected from one brackishwater and one nearby freshwater fish pond where no tidal water is allowed to enter. The distance between the two types of ponds, however, did not exceed 0.5 km in any instance. After collection the soils were air dried, ground, passed initially through a 2 mm and then through a 80 mesh sieve and used for subsequent analyses.

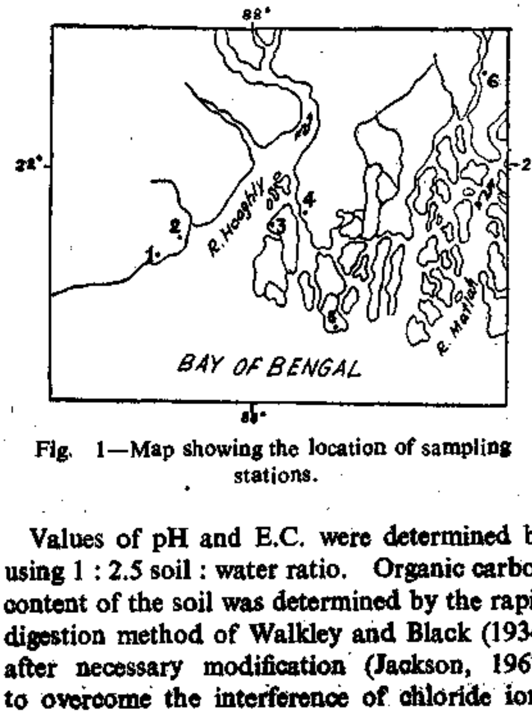

Fig. 1—Map showing the location of sampling stations.

Values of pH and E.C. were determined by using 1 : 2.5 soil : water ratio. Organic carbon content of the soil was determined by the rapid digestion method of Walkley and Black (1934) after necessary modification (Jackson, 1967) to overcome the interference of chloride ions in saline soils. Free calcium carbonate was determined by the method described by Piper (1966), available nitrogen content of the soil by using alkaline permanganate method of Subbiah and Asija (1956) and available phosphorus content by the method of Olsen *et al.* (1954).

RESULTS AND DISCUSSION

Results of different analyses have been presented in Table 1. As evidenced from the Table, pH values of the studied soils did not vary very much between the two types of ponds with average values of 7.7 and 7.5 for brackishwater and freshwater pond soils respectively. Slightly alkaline pH values for brackishwater pond soils were as expected, since the soils of such ponds remain submerged under highly saline tidal water. As indicated from the E.C. values, the soils of freshwater ponds were also rich in soluble salts due to being situated in low lying coastal areas and this resulted in slightly alkaline pH values of the soils also. Importance of neutral to slightly alkaline pH values on productivity of fish ponds has been discussed by Ohle (1938), Alikunhi (1957) and many others. Hence the obtained pH values for all the studied brackishwater and freshwater pond soils may be considered to be favourable for aquaculture.

E.C. values of the soils of brackishwater ponds were higher than those of freshwater ponds with average values of 6.9 and 3.5 mm hos/cm respectively, obviously due to the former remaining submerged under highly saline tidal water. Freshwater pond soils although showed lower E.C. values than brackishwater ponds, it was rather higher in comparison to the values generally obtained in case of freshwater pond soils. These freshwater ponds are situated in low lying coastal areas, soils of which are highly saline in nature. This resulted in comparatively higher E.C. values of the soils although no tidal water was allowed to enter in such ponds. Paliwal (1972) has described

TABLE 1. *Some important characteristics of the brackishwater and nearby freshwater pond soils*

Location Name	Type	pH	E.C. (mmhos/cm)	$CaCO_3$ (%)	Available N_2 (mg/100g soil)	Available P (mg/100g soil)	Organic carbon (%)
Digha	B	7.5	7.4	2.0	12.6	1.7	0.13
	F	7.4	3.2	2.0	10.2	1.6	0.11
Junput	B	8.0	7.8	2.5	8.4	3.1	0.10
	F	7.7	4.1	2.0	7.8	3.2	0.10
Sagar	B	8.3	6.1	4.0	10.8	3.1	0.33
	F	7.4	3.2	2.5	19.6	1.4	0.78
Kakdwip	B	7.7	8.2	2.7	8.8	1.6	0.33
	F	8.2	5.0	2.2	14.0	1.2	0.35
Bakkhali	B	7.0	6.1	3.0	11.2	3.7	0.41
	F	7.1	2.4	2.5	15.0	0.8	0.78
Canning	B	7.6	6.1	3.1	10.6	2.4	0.30
	F	7.5	3.4	2.4	14.8	1.5	0.24
Average	B	7.7	6.9	2.9	10.4	2.6	0.27
	F	7.5	3.5	2.3	13.6	1.6	0.24

B — Brackishwater F — Freshwater

decomposition of organic matter to be lower under high E.C. values. The results of the present study, therefore, indicate that decomposition of organic manures in brackishwater fish ponds may be adversely affected by the highly saline condition of the ponds and hence use of previously decomposed organic manures may be beneficial for improving productivity of such ponds.

Free $CaCO_3$ content of the soils ranged between 2.0 to 4.0 per cent for brackishwater ponds and between 2.0 to 2.7 per cent for freshwater ponds with average values of 2.9 and 2.3 per cent respectively.

Available nitrogen levels were rather low in both the two types of pond soils with average values of 10.4 mg/100 g soil in case of brackishwater ponds and 13.6 mg/100 g soil in case of freshwater ponds while Banerjea (1967) indicated the critical value of available nitrogen in freshwater fish ponds as 25 mg/100 g soil. Presence of organic matter is known to influence the amount of available nitrogen content of the soils to a large extent. In the present study also the freshwater pond soil of location 3, Sagar island, showing the highest amount of organic carbon among all the studied soils recorded the highest value of nitrogen in available form. On the other hand, both the freshwater and brackishwater ponds of location 2, Junput, recording the minimum value of organic carbon, also showed lowest amounts of available nitrogen in the soils. Pillay *et al.* (1962) observed productivity of brackishwater ponds to depend largely on the amount of available nitrogen in the bottom soils and hence the low values obtained in the present study emphasize the need for application of comparatively higher amount of nitrogen in brackishwater ponds in the form of organic manures or inorganic fertilizers than what is generally used for freshwater ponds.

Amount of available phosphorus in brackishwater pond soils assumed comparatively higher values over freshwater ponds with corresponding average values of 2.6 and 1.6 mg/100 g soil. Higher amount of available phosphorus in brackishwater pond soils has been reported by Chattopadhyay (1978) and may be considered favourable for brackishwater fish culture not only due to the fact that phosphorus is one of the essential nutrient elements for pond productivity and which often occurs in very meagre amount in nature but also due to its importance in the growth and multiplication of blue green algae which form the major fish food organisms in brackishwater ponds.

Organic carbon content of the soils of brackishwater ponds were comparatively lower than that of the freshwater ponds with respective average values of 0.27 per cent and 0.42 per cent. Banerjea (1967), while describing productivity of freshwater fish ponds in relation to chemical condition of pond soil and water, reported pond soils having less than 0.5 per cent organic carbon to be low in productivity. Assessing from his criterion, the studied freshwater pond soils of the coastal West Bengal may, in general, be considered to be low in productivity even with the comparatively higher organic carbon value of freshwater pond soils over the brackishwater pond soils. Occurrence of lower amount of organic carbon in brackishwater fish pond soils of West Bengal is in agreement with the observations of Chattopadhyay (1978). Accumulation of organic carbon in fish pond soils has been attributed largely to the production of planktonic and bacterial mass by Hepher (1965). Hence lack of presence of sufficient fish food organisms in brackishwater ponds (Bhimachar and Tripathi, 1966) may be the reason of this lower amount of organic carbon in such soils. Tang and Chen (1967) showed that the productivity of brackishwater fish ponds increases with the organic matter content of the bottom soils. Hence the low values of the studied brackishwater pond soils indicate that application of organic manures in comparatively higher doses may be beneficial to increase the productivity of such ponds.

The present study, therefore, indicates that the soils of brackishwater fish ponds of West Bengal have comparatively higher amount of available phosphorus but lesser amount of available nitrogen and organic carbon than those of nearby freshwater ponds. Hence use of organic manures and nitrogenous fertilizers in comparatively higher doses may be beneficial for obtaining higher production in such ponds.

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ECOLOGY OF THE COCONUT HUSK RETTING GROUNDS IN KERALA

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ABSTRACT

Extensive retting of coconut husk has become one of the most important causes of large-scale pollution in most of the shallow, brackish and backwater systems in Kerala.

The ecology of a retting zone has been studied in comparison with a non-retting area in the backwater system by fortnightly estimations of dissolved oxygen, hydrogen sulphide, salinity, hydrogen-ion-concentration, phosphate, nitrate, plankton, benthos and nekton. Data on rainfall, river discharge, condition of the bar opening, air temperature and surface water temperature also were taken regularly.

A remarkable feature associated with retting was the complete depletion of oxygen leading to anoxic condition that lasts for several months. Substantial quantities of hydrogen sulphide had also been found in the surface water leading to the formation of a unique sulphide system, the like of which has not been reported from any other biotope so far.

The nature of the zooplankton and benthic communities have been examined in detail. The fauna of the retting zone have been severely depleted when compared with the non-retting zone. The study has brought to light the existence of a highly diverse invertebrate fauna associated with this sulphide biome and it was discussed with the information available on similar sulphide biomes of the world.

The fishery survey conducted as part of the present investigation showed that the commercially important prawns, fishes and mussels are absent in the retting zone and the area does not support any worthwhile fishery.

INTRODUCTION

AN OUTSTANDING phenomenon of the south-west coast of India bordering the State of Kerala is its long system of backwaters roughly parallel to the Arabian Sea. The shores of these back-waters are skirted with dense gardens of coconut palms. A majority of the 400 crores of coco-nuts produced in Kerala is harvested from the shores of these backwaters. This plentiful availability of coconut husk and the vast stretch of shallow brackishwater lakes have led to the growth of coir industry into a massive cottage industry in the state providing direct employ-ment to nearly 800,000 peolpe and indirect employment to as many as 10,000,000 people. India produces about 1.55 lakh tonnes of coir goods and Kerala's contribution to this overall production now stands at a little less than 80 per cent.

Retting is the basic process involved in the manufacture of coir. Fresh coconut husks, steeped in the shallow regions of the back-waters or in special pits adjacent to them are allowed to remain soaked in water for various periods ranging from 4-12 months. The husks become softened and the fibres get loosened during this period. The rotten husks, reclaimed manually are processed to make the 'golden fibre'. Kerala's coastal belt is scattered with hundreds of such retting grounds. The major areas are shown in Fig. 1. No study has hitherto been reported regarding the ecology of these coconut husk retting grounds in the Kerala backwaters. The present study has been undertaken to elucidate the ecology of a typical retting ground in one of Kerala's backwaters. The work was initiated in February 1974 and the results of the investigation are briefly presented in this paper.

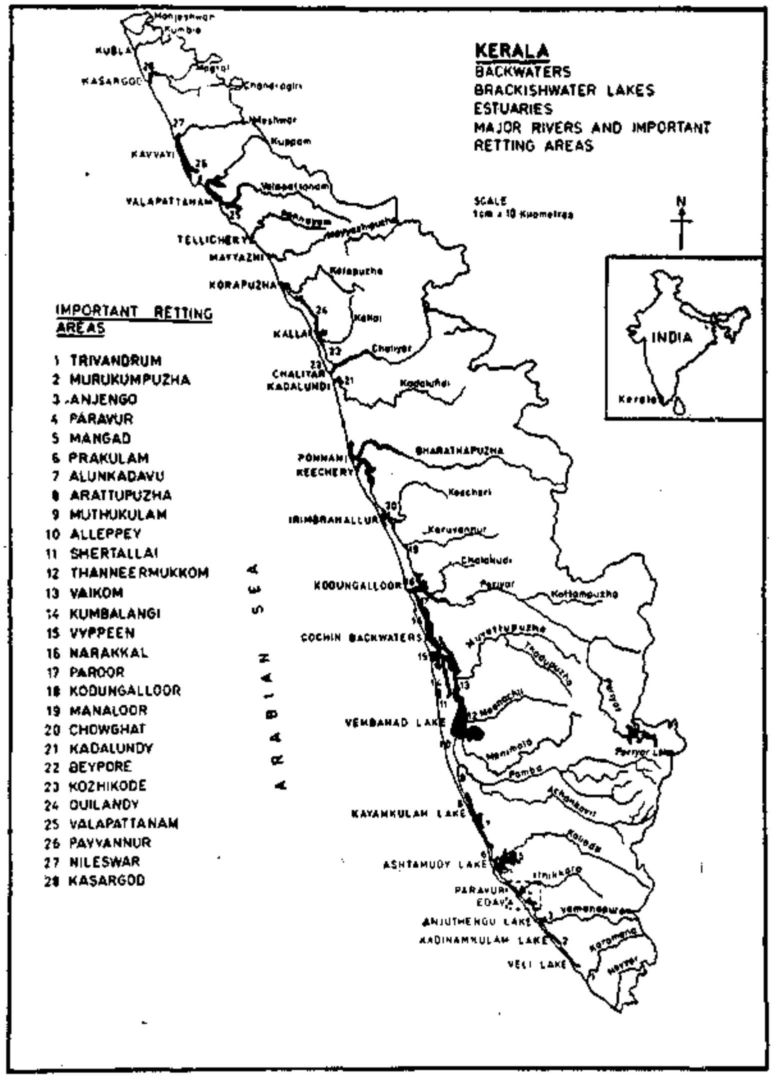

Fig. 1. Important Coconut husk retting areas in Kerala.

AREA OF STUDY

The present investigation was carried out in the Edava Nadayara-Paravur Backwater system lying in the Quilon District of Kerala State between latitudes 8°46′N and 8°51′N and longitudes 76°36′E and 76°43′E. Figure 2 shows the location of the two stations. Station I is a major retting zone in the Kerala backwaters and station II an area free from retting activity. The Paravur Canal 2.41 Km long connects the Paravur backwater with the Edava-Nadayara backwater. The Ithikkara River originating from the Madathurikunnu, after flowing for about 45 Km drains into the Paravur Backwater near Mayyanadu. A flood water outlet channel about 30 m wide with a screw gear shutter regulator and a seasonal bar opening are important features of the Paravur Backwater.

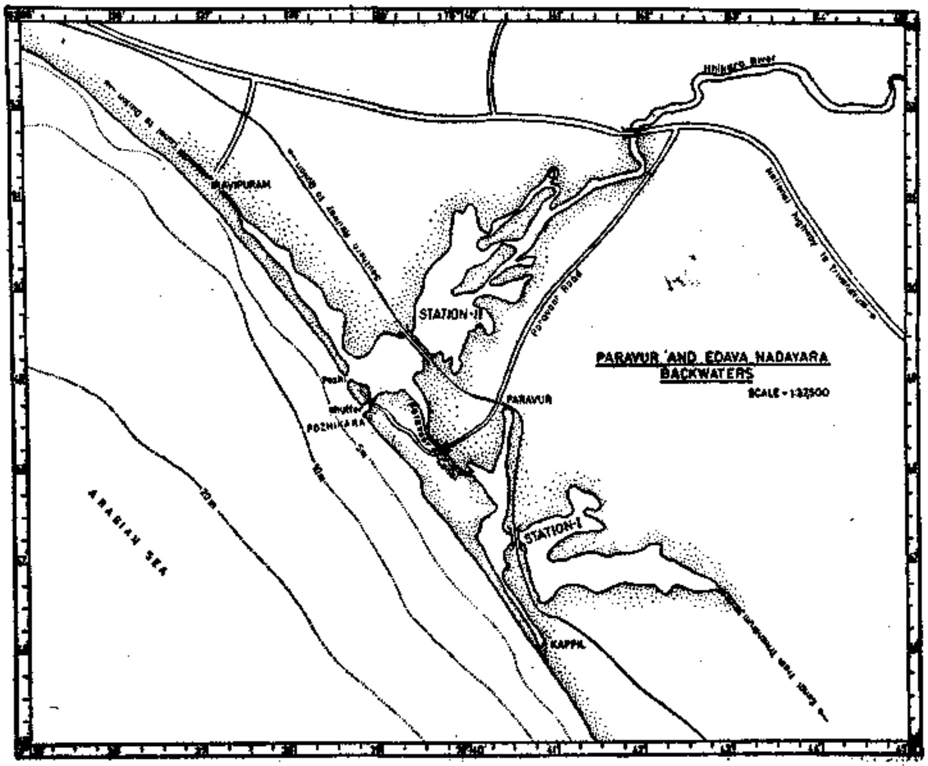

Fig. 2. Paravur and Edava-Nadayara Backwater in Kerala.

Material and Methods

Fortnightly samples were taken from both the retting and non-retting zones for the estimation of dissolved oxygen, hydrogen sulphide, salinity, pH, phosphate, nitrate, plankton, benthos and nekton. The data on the above parameters constituted the material for the present study. Surface water temperature was recorded with a centigrade thermometer. Dissolved oxygen was determined by Winkler's method. Salinity was determined by Mohr's method of titration of the chlorides with silver nitrate using potassium dichromate as the indicator. Hydrogen sulphide was estimated using the method given by Golterman and Clymo (1969), pH with the help of a pH meter, phosphates and nitrates using methods described by Strickland and Parsons (1972). Plankton samples were collected with a half metre tow net made of fine organdie silk (36 strands/cm) hauled from a boat. The samples were preserved following the procedure of Currie (1963) and examined using standard methods (Tranter, 1960). Samples for benthic study were taken with the help of a tin corer just over 6,6 cm internal diameter and 21 cm length. The extraction techniques of Hulings and Gray (1971), Holme and McIntyre (1971), Uhlig (1968) and Uhlig *et al.* (1973) were suitably adapted to separate as much organisms as possible. A general survey was conducted to assess the impact of retting upon the fishery of the retting and non-retting zones. Data on rainfall and river discharge were collected from the Kerala Engineering Research Institute, Peechi.

RESULTS

Meteorological conditions

The data on rainfall and river discharge and conditions of the bar are given in Table 1. The area received heavy rainfall from the south-west monsoon and some precipitation from the north-east monsoon. The maximum rainfall was experienced in July and the monsoon months alone recorded a total precipitation of 2333.9 mm, the total for the year being 3358.2 mm. Rainfall and river discharge are closely related, the latter following the trends in the former. The sand bar was removed twice during the period and the entire backwater system remained open to the sea from early April to November and also in early January. During the period when the bar was open both the stations experienced the effects of tides of the open sea.

Physico-chemical characters

Tables 2 and 3 present the fortnightly variations of temperature, salinity, dissolved oxygen, dissolved hydrogen sulphide, hydrogen ion concentration, phosphate-phosphorus and nitrate nitrogen of the surface waters at stations I and II respectively.

The surface water temperature at station I ranged from 26.5 to 32.0°C, salinity from 0.39 to 9.90‰, dissolved oxygen from zero to 7.16 ml/L, hydrogen sulphide from zero to 52.46 mg H_2S/L, pH from 4.20 to 8.90, phosphate zero to 1.33 μg at. PO_4 P/L and nitrate from zero to 1.41 μg at. NO_3 N/L. At station II temperature varied from 25.5 to 33.0°C, salinity from 0.75 to 20.30‰, dissolved oxygen from 3.64 to 11.05 ml./L, pH from 6.7 to 8.4, phosphate from zero to 1.29 μg at. PO_4 P/L and nitrate from zero to 0.66 μg at. NO_3 N/L.

TABLE 1. *Data on rainfall, river discharge and the condition of the sand bar during* 1974-1975

Season	Month	Total Rainfall (mm)	Total River discharge Mm^3	Gut open/closed
	Feb. '74	—	5.23	closed
Pre-monsoon	Mar.	48.30	4.58	closed
	Apr.	119.60	9.11	open
	May	600.80	32.42	open
	June	397.70	64.92	open
Monsoon	July	948.40	115.50	open
	Aug.	651.00	171.24	open
	Sep.	336.80	107.02	open
	Oct.	170.90	90.37	open
Post-monsoon	Nov.	78.40	80.01	open
	Dec.	—	94.90	closed
	Jan. '75	6.30	—	open

TABLE 2. *Fortnightly variations of the physico-chemical conditions at the retting zone during* 1974-'75 (*Station I*)

Season	Month	Surface water temperature (°C)	Salinity (‰)	Oxygen (ml/L)	Hydrogen sulphide mg.H_2S/L	pH	Phosphate (μg-at. PO_4-P/L)	Nitrate (μg-at. NO_3-N/L)
Pre-monsoon	Feb. '74	27.00	5.12	—	11.34	7.30	0.37	—
		30.00	5.68	—	10.59	7.30	0.09	0.49
,,	Mar.	30.00	6.08	—	44.39	7.20	0.02	0.46
		31.00	7.05	—	41.60	7.15	0.15	0.05
,,	Apr.	32.00	6.89	—	41.85	8.90	1.33	—
,,	May	31.50	7.72	—	49.95	7.65	0.62	—
		28.00	9.07	—	39.08	7.30	0.60	—
Monsoon	June	29.50	9.07	—	52.46	8.60	0.36	0.05
		30.00	9.78	—	28.25	8.40	0.24	0.02
,,	July	28.00	9.90	—	45.65	7.70	0.84	0.07
		27.50	2.02	—	45.92	6.30	0.11	1.41
,,	Aug.	28.00	1.48	3.24	38.34	4.20	0.13	—
		28.00	2.38	3.66	—	4.60	—	0.12
,,	Sep.	30.00	0.40	1.33	0.15	7.10	—	—
		27.00	1.11	2.00	0.16	7.90	—	—
Post-monsoon	Oct.	27.50	0.39	7.17	0.14	7.60	—	0.99
		27.50	2.46	1.83	3.03	7.10	—	—
,,	Nov.	31.50	4.02	—	5.50	6.55	—	0.05
		32.00	4.85	—	7.60	6.70	0.02	0.06
,,	Dec.	27.50	4.78	—	8.10	6.80	0.15	0.22
		26.50	3.75	—	8.83	6.50	0.17	0.23
,,	Jan. '75	27.00	3.60	—	29.98	6.70	0.20	0.19
		27.50	4.16	—	47.16	6.90	0.18	—

TABLE 3. *Fortnightly variations of the physico-chemical condition at the Paravur Backwater* (*Station II*) *during* 1974-'75

Season	Month	Surface water temp. (°C)	Salinity (‰)	Oxygen (ml/L)	pH	Phosphate (μg-at. PO_4-P/L)	Nitrate (μg-at. NO_3-N/L)
Pre-monsoon	Feb. '74	27.00	7.32	5.95	6.90	0.07	0.02
		30.50	7.59	5.33	8.10	0.18	0.66
,,	Mar.	31.50	6.70	3.64	7.10	0.18	0.44
		32.00	7.45	3.78	7.20	0.27	0.22
	Apr.	31.00	4.16	5.12	7.70	—	0.39
,,	May	30.50	11.38	6.74	8.10	—	0.12
		33.00	20.30	4.85	7.80	0.06	—
Monsoon	June	30.00	2.79	7.15	7.60	0.06	0.39
		29.00	8.41	5.66	8.30	0.09	0.32
,,	July	28.00	7.45	8.36	7.85	—	0.15
		27.00	4.33	8.49	8.40	—	0.05
	Aug.	28.00	6.24	11.05	8.20	0.02	—
		27.50	6.35	6.83	8.10	0.15	0.12
,,	Sep.	28.00	8.26	7.33	7.50	0.02	0.07
		27.50	0.93	9.32	7.90	—	0.07
Post-monsoon	Oct.	29.00	2.38	6.99	7.80	—	0.05
		28.50	2.23	6.49	7.50	—	—
,,	Nov.	29.50	0.75	6.53	7.30	0.09	0.12
		30.00	0.81	5.00	6.90	0.06	0.13
,,	Dec.	29.00	1.28	5.25	6.75	0.06	0.15
		25.50	1.53	5.85	6.70	1.00	0.44
,,	Jan. '75	27.00	2.21	5.60	7.25	1.29	—
		29.00	5.41	5.20	7.50	—	—

Plankton

Tables 4 and 5 present the quantitative fortnightly distribution (%) of the major groups of plankton at station I and II respectively.

A casual look at the collection revealed the fact that the plankton at station I was quantitatively and qualitatively poorer in comparison with station II. Insects, copepods, rotifers and nematodes constituted the dominant groups of plankton at the retting zone while coelenterates, copepods, branchiopods, amphipods, tanaids, crustacean larvae, *Lucifer*, insects and fish larvae formed the plankton of the non-retting zone. The fortnightly variations in the percentage distribution of the total planktonic organisms were significant at 1% level between the two stations.

No phytoplankton could be recorded from the retting zone. At the non-retting zone diatoms of the genus *Rizosolenia, Chaetoceros, Pleurosigma, Coscinodiscus, Biddulphia, Nitzschia* and *Skeletonema* were found to occur in varying densities. The dinoflagellates were represented by *Ceratium* sp.

Hydromedusae were absent at station I, Whereas at station II it was represented by *Obelia* spp. The nematode population was composed of *Desmodora* sp., *Sabatiera intermissa* Wieser and *Dorylaimus* sp. The period April-October 1974 was not favourable for this group. Annelids in the plankton were represented by a few polychaetes of the family Nereidae. Copepods constituted the major component of plankton at both the stations. Of the eleven species identified in station II only four species occurred in station I. In the retting zone, the population was maximum in August whereas in the non-retting zone it was in February. The density differences between the two stations were significant at 1% level. The copepods were represented by sub-orders Calanoida, Cyclopoida and Harpacticoida. The branchiopods also constituted a major element of the plankton at both the stations, the differences being significant at 5% level. Tanaids, amphipods and decapods were totally absent at station I. At station II the decapods were represented by different stages of *Lucifer* sp., larvae of *Caridean* sp. and *Penaeus* sp. and zoea larvae of brachyurans. Insects represented a major group at station I, consisting of the larvae of *Culex*, moults of *Tendipes* and *Chironomus* larvae. Rotifers were present only at station I. Molluscs were represented by a few lamelli branch and gastropod larvae. Fish larvae occurred regularly in the plankton at station II while it occurred only once in station I.

Benthos

Tables 6 and 7 present the quantitative fortnightly variation (%) of the major groups of benthic fauna at stations I and II respectively. An examination of the general composition of the bottom communities in the retting and non-retting zones revealed that the fauna is quantitatively and qualitatively poorer in the former than in the latter zone. The benthic fauna at the retting zone was composed of nematodes, oligochaetes, polychaetes, harpacticoids, amphipods, tanaids, *chironemus* larvae and molluscs. The fauna at the non-retting zone was richer in terms of number of groups represented and total counts. In addition to the groups mentioned above, the non-retting zone recorded the occurrence of foraminifers, gastrotrichs, calanoid copepods, isopods and brachyuran decapods. The density of the benthic fauna was greater at station II during all the seasons. The monsoon season recorded a poor fauna at both the stations. The density of the population was highest at both the station during the post-monsoon season.

The foraminifers were completely absent in the retting zone. Nematode population was maximum at station I in December and at station II, in October, both during the post-monsoon period. Of the ten species of nematodes only 3 species occurred in the retting

TABLE 4. *Quantitative fortnightly distribution (%) of the major groups of zooplankton at retting zone (Station I) during* 1974-'75

Season	Month	Nematoda	Polychaeta	Copepoda	Cladocera	Decapod larvae	Insecta	Rotifera	Mollusca	Fish larvae	Eggs
Pre-monsoon	Feb. '74	0.73	—	3.72	—	—	1.23	2.31	—	—	0.20
		0.15	—	0.70	—	—	0.91	11.56	—	—	—
,,	Mar.	0.10	—	2.39	—	—	0.78	2.31	—	—	—
		—	—	2.37	—	50.00	0.90	9.34	—	—	0.20
,,	Apr.	—	—	0.87	—	—	4.51	—	—	—	—
,,	May	—	—	0.17	—	—	2.10	—	—	—	—
		—	—	10.45	—	—	2.41	—	—	—	—
Monsoon	June	—	—	1.86	—	—	7.34	—	—	—	—
		—	—	1.09	—	—	3.61	9.25	—	—	1.10
,,	July	—	—	3.75	—	—	40.44	—	—	—	0.40
		—	—	4.41	—	50.00	8.98	—	—	—	0.41
,,	Aug.	—	—	22.13	58.71	—	9.58	—	—	—	0.45
		—	—	2.72	—	—	5.99	—	100	100	0.49
,,	Sep.	—	—	10.04	9.63	—	4.19	16.23	—	—	0.20
		—	—	16.88	14.33	—	2.10	4.72	—	—	0.10
Post-monsoon	Oct.	—	—	0.25	17.33	—	1.20	2.45	—	—	12.09
		3.80	—	3.99	—	—	0.66	0.19	—	—	0.10
,,	Nov.	5.68	100	0.94	—	—	0.61	11.56	—	—	0.20
		6.39	—	0.50	—	—	0.60	6.94	—	—	0.10
,,	Dec.	67.98	—	3.02	—	—	—	4.63	—	—	81.00
		11.96	—	0.34	—	—	0.60	6.94	—	—	1.79
,,	Jan. '75	1.93	—	6.23	—	—	0.62	9.25	—	—	0.89
		1.28	—	1.17	—	—	0.65	2.31	—	—	0.70

TABLE 5. *Quantitative fortnightly distribution (%) of the major groups of zooplankton at non-retting zone (Station II) during 1974-'75*

Season	Month	*Ceratium*	Hydro-medusa	Poly-chaeta	Cope-poda	Clado-cera	Tanaid-acea	Amphi-poda	Decapod larvae	Lucifer	Insecta	Mollusca	Fish larvae	Eggs
Pre-monsoon	Feb. '74	—	—	13.33	26.99	—	11.40	0.45	6.00	0.44	51.38	—	3.55	—
		—	0.70	6.67	20.27	—	12.92	6.73	3.88	8.29	15.43	—	3.55	—
,,	Mar.	—	0.70	6.67	12.12	—	15.20	6.73	4.23	13.52	7.57	80.63	5.52	—
		—	0.70	40.00	2.07	—	16.41	4.49	6.70	27.79	0.87	16.51	5.32	—
,,	Apr.	—	0.70	13.33	7.28	6.35	13.68	4.49	3.17	5.32	0.29	2.54	3.96	—
,,	May	—	2.11	—	11.33	16.57	11.40	0.22	2.47	5.23	0.15	0.32	2.18	—
		—	3.52	—	0.15	7.25	9.12	0.44	2.29	12.21	0.44	—	1.77	—
Monsoon	June	—	90.14	—	0.61	6.59	7.60	4.49	3.88	3.35	0.73	—	1.39	—
		—	1.41	—	2.93	52.37	2.28	5.38	4.94	9.72	7.57	—	0.60	—
,,	July	—	—	—	1.28	3.47	—	6.73	5.29	4.49	—	—	9.09	—
		—	—	—	5.85	2.29	—	3.59	1.07	0.45	—	—	2.40	—
,,	Aug.	0.26	—	—	2.99	—	—	2.69	—	3.05	—	—	1.58	—
		1.88	—	—	0.58	—	—	2.24	—	3.49	—	—	0.99	—
,,	Sep.	93.62	—	—	0.43	2.19	—	0.90	1.41	—	—	—	2.37	—
		3.84	—	—	1.47	0.21	—	0.56	2.47	0.03	—	—	2.76	0.16
Post-monsoon	Oct.	0.41	—	—	0.15	2.50	—	0.18	3.88	—	0.73	—	0.18	31.62
		—	—	—	0.45	0.21	—	11.22	14.46	—	—	—	2.17	15.81
,,	Nov.	—	—	—	0.12	—	—	0.54	8.82	—	—	—	0.59	0.47
		—	—	—	0.25	—	—	2.24	3.88	0.44	—	—	0.20	4.11
,,	Dec.	—	—	—	0.07	—	—	20.19	6.00	—	—	—	0.59	27.67
		—	—	—	0.21	—	—	8.97	6.35	—	—	—	27.20	8.14
,,	Jan. '75	—	—	—	0.70	—	—	4.49	2.47	1.31	—	—	11.43	7.91
		—	—	20.00	1.71	—	—	2.34	6.35	0.87	14.85	—	10.64	4.11

TABLE 6. *Quantitative fortnightly variation of the major groups of benthic fauna (%) at retting zone (Station I) during 1974–'75*

Season	Month	Nematoda	Oligochaeta	Polychaeta	Harpacticoida	Amphipoda	Tanaidacea	*Chironemus* larvae	Mollusca	Eggs
Pre-monsoon	Feb. '74	0.62	—	25.83	2.44	63.03	15.79	21.15	50.00	—
		1.86	—	48.33	7.32	7.56	5.26	0.96	18.18	—
,,	Mar.	—	24.00	5.83	14.63	2.52	—	3.85	—	—
		—	12.00	1.67	12.20	0.84	—	2.88	—	—
,,	Apr.	11.18	—	—	17.07	—	—	2.88	—	—
,,	May	4.97	—	—	2.44	—	—	0.96	—	—
		2.48	12.00	—	—	—	—	2.88	—	—
Monsoon	June	6.83	16.00	—	—	—	—	0.96	—	—
		—	8.00	—	—	—	—	0.96	—	—
,,	July	—	6.00	8.33	—	6.72	—	0.96	—	—
		—	22.00	5.00	—	5.04	—	0.96	—	—
,,	Aug.	1.86	—	0.83	—	2.52	—	—	—	—
		—	—	—	—	4.20	28.07	—	4.55	—
,,	Sep.	—	—	—	—	3.36	15.79	—	4.55	—
		—	—	1.67	2.44	1.68	22.81	—	13.64	—
Post-monsoon	Oct.	—	—	0.83	9.76	1.68	8.77	—	9.09	—
		9.94	—	0.83	4.88	0.84	3.51	3.85	—	—
,,	Nov.	—	—	0.83	19.51	—	—	6.73	—	—
		—	—	—	7.32	—	—	8.65	—	—
,,	Dec.	60.25	—	—	—	—	—	6.73	—	74.92
		—	—	—	—	—	—	10.58	—	25.08
,,	Jan. '75	—	—	—	—	—	—	6.73	—	—
		—	—	—	—	—	—	17.31	—	—

TABLE 7. *Quantitative fortnightly variation of the major groups of benthic fauna (%) at non-retting zone (Station II) during* 1974-'75

Season	Month	Foraminifera	Nematoda	Gastrotricha	Oligochaeta	Polychaeta	Calanoida	Harpacticoida	Amphipoda	Isopoda	Decapoda	Tanaidacea	*Chironemus* larvae	Mollusca
Pre-monsoon	Feb. '74	—	7.34	—	—	9.15	—	—	34.83	5.88	7.69	16.22	10.94	0.88
		—	—	—	—	3.70	—	—	13.81	15.69	7.69	5.41	62.50	7.89
,,	Mar.	—	—	—	—	9.37	—	14.29	4.20	7.84	—	27.03	—	—
		—	—	—	—	1.09	—	9.52	3.30	31.37	7.69	18.92	—	66.67
,,	Apr.	—	6.21	—	—	—	—	4.76	2.40	5.88	—	6.31	—	—
,,	May	—	2.82	14.29	—	—	—	—	0.30	—	—	—	—	—
		20.00	7.91	—	—	—	—	—	—	—	—	—	—	—
Monsoon	June	—	2.26	—	16.22	—	4.00	—	1.20	—	—	2.70	6.25	1.75
		—	—	7.14	35.14	—	—	—	0.90	—	—	2.70	1.56	—
,,	July	—	1.13	35.71		0.22	—	—	1.50	—	—	0.90	6.25	—
		—	15.82	28.57	—	0.87	—	—	2.70	—	—	—	4.69	—
,,	Aug.	—	10.17	14.29	—	—	4.00	—	1.80	—	—	—	—	—
		—	—	—	—	0.87	—	—	7.51	—	—	—	—	—
,,	Sep.	—	0.56	—	—	0.44	—	—	1.80	—	—	1.80	—	—
		—	2.26	—	—	0.65	—	—	0.90	—	—	0.90	—	—
Post-monsoon	Oct.	—	13.56	—	—	5.88	8.00	9.52	0.90	—	—	—	—	—
		20.00	21.47	—	—	5.23	—	7.14	1.20	11.76	—	—	—	19.30
,,	Nov.	40.00	—	—	—	7.84	—	28.57	3.30	—	15.38	0.90	—	—
		20.00	8.47	—	—	39.87	—	16.67	—	—	38.46	6.31	—	—
,,	Dec.	—	—	—	—	11.33	—	7.14	—	—	23.08	4.50	—	—
		—	—	—	10.81	1.09	—	2.38	0.90	1.96	—	2.70	—	—
,,	Jan. '75	—	—	—	16.22	1.74	40.00	—	2.40	1.96	—	2.70	4.69	—
		—	—	—	21.62	0.65	44.00	—	14.11	17.65	—	—	3.13	3.51

zone. Gastrotrichs were present only at station II. Oligochaetes appeared at both the stations, recording their maximum at station I in March and at station II in June. Polychaetes also occurred at both the stations in good numbers. The population was composed of five species of which only four occurred at station I. Calanoid copepods, present only at station I registered their maximum in December. Harpacticoid copepods were present at both the stations recording their maximum in November. Amphipod, constituted a major group at both the stations registering their peak in February. The amphipod population was composed of six species belonging to four families of which only two species occurred in the retting zone. Isopods and decapods were present only at station II. Tanaids occurred at both the stations. The maximum at station I was recorded in August and at station II in March. The benthic insect fauna at both the stations was solely

TABLE 8. *Species of fishes, prawns, crabs and molluscs collected from Stations I and II*

Station I		Station II
	Fishes	
Puntius bimaculatus		*Puntius bimaculatus*
Tachysurus caelatus		*Tachysurus caelatus*
Panchax lineatus		*Panchax lineatus*
Channa striatus		*Mugil cephalus*
Pertica filamentosa		*Ambassis dayi*
Etroplus maculatus		*Ambassis commersoni*
Etroplus suratensis		*Epinephelus tauvina*
Anabas testudineus		*Apogon thermalis*
Macropodus cupanus		*Sillago sihama*
Oligolepis acutipennis		*Selar kalla*
Cynoglossus macrostomus		*Carangoides praeustus*
Chelonodon patoca		*Caranx sexfasciatus*
		Gerreomorpha setifer
		Etroplus maculatus
		Etroplus suratensis
		Callionymus sp.
		Glossogobius giuris
		Acentrogobius ornatus
		Cynoglossus macrostomus
	Prawns	
Nil		*Penaeus indicus*
		Penaeus monodon
		Metapenaeus monoceros
		Metapenaeus dobsoni
		Macrobrachium idella
	Crabs	
Nil		*Scylla serrata*
		Neptunus pelagicus
	Molluscs	
Nil		*Villorita cochinensis*
		Corbicula striatella

represented by the *Chironomus* larva. An important group in the benthic community, it was maximum at both the stations in February. The mollusc population was maximum at station I in February and at station II in March. Large number of eggs, chiefly of fishes were found in the benthos at station I in the month of December.

Fisheries

Table 8 presents the species-wise distribution of fishes, prawns, crabs and molluscs at stations I and II. The present observation indicates the nature of depletion of the fauna that has taken place in the retting zone consequent on the years of retting activity in the region. Of the 25 species of fishes, 5 species of prawns, two species each of crabs and molluscs recorded from both the two stations only twelve species of fishes were recorded from the retting zone. The air breathing fishes like *Channa striatus* and *Anabas testudineus* and Larvicidal fishes like *Etroplus suratensis*, *E. maculatus* and *Macropodus cupanus* were the chief representatives typical of the retting zone. No significant fishery existed here. At the non-retting zone the fish fauna was composed of 19 species of fishes, the prawns by five species, the crabs and molluscs by two species each. This area supported a rich fishery composed of prawn (63%), mullets (8%), pearlspots (11%), carangids (5%), gobioids (7%), Catfish (4.5%) and other miscellaneous groups (1.5%).

Discussion

The Edava-Nadayara Backwater has its sand bar at Kappil and that of the Paravur backwater at Pozhikkara (Fig. 2). While the retting zone in the Edava-Nadayara backwater was virtually a cesspool of dark, foul smelling stagnant water for almost the whole year of investigation, the non-retting zone (the Paravur backwater) presented the picture of a highly dynamic, productive estuary during most of the year with a rich fauna of plankton, benthos and fishes. The rainfall and the opening of the sand bar led to extensive changes in the hydrobiological conditions at both the retting and non-retting zones. On the basis of the fluctuations in the principal hydrographic characters, planktonic and benthic communities the year has been divided into pre-monsoon from February to May, the monsoon from June to September and the post-monsoon from October to January. This division agrees well with the divisions postulated by earlier workers (George and Kartha, 1963; Nair, 1965; Rajan, 1972; Pillai, 1974; Sobhana, 1976). The period of heavy rain falls and river discharge coincided with wide fluctuations in salinity and temperature.

Oxygen and hydrogen sulphide

Prolonged periods of anoxic condition associated with high concentrations of hydrogen sulphide has been the most characteristic feature of the retting zone. Highly restricted circulatory process and the higher consumption of oxygen for organic decomposition can be attributed as the reasons for this unprecedented levels of oxygen depletion. The hydrogen sulphide concentrations have been the highest, recorded from any water body. This anoxic, hydrogen sulphide pervading biome has been designated as 'Sulphureta'. The incredibly large quantity of husk regularly burried in the waters and the resulting stagnant conditions are found to be factors important in the vast depletion of the oxygen reserve and the consequent formation of hydrogen sulphide. The mechanical action of the gas bubbles that rise from the bottom is also suspected to induce depletion of oxygen in the retting zone.

The evolution of hydrogen sulphide was a very prominent feature marked by the pronounced stench of the gas. It was Prabhu (1957) and Pandalai *et al.* (1957) who first postulated the production of hydrogen sulphide associated with the retting of coconut husk.

The present investigation has found an inverse relationship between the distribution of oxygen and hydrogen sulphide. Their correlation coefficient (r) is —0.44 and this is significant at 5% level. A hydrogen sulphide system very similar to the carbon dioxide system is suspected to prevail in the retting zone of the backwater system.

Size of the sulphureta

The 'Sulphureta' in the Edava-Nadayara Backwater is found to be quite extensive considering the area utilised for retting. Fenchel and Riedl (1970) reported the existence of a sulphide biome beneath the oxidised surface layers of marine sandy sediments. In the retting zone, its existence has been found from the surface waters down to the bottom and deeper into the sediment layers. After the heavy monsoon rains, although the surface water, for a while becomes enriched with oxygen, there remains beneath the surface aerobic waters, the anoxic sulphide biome, still reaching to the depth of the retting zone. This is a striking feature in the Edava-Nadayara region. Water charged similarly with hydrogen sulphide have been reported from brackish seas like the Baltic and in some of the Norwegian Fjords (Thomsen, 1931; Nikitin, 1931; Strom, 1936; Ivanenkov and Rozanov, 1961; Fonselius, 1962; Richards, 1965; Theede *et al.*, 1969; Emery, 1969). At station II the water was rich of dissolved oxygen and devoid of hydrogen sulphide.

Hydrogen ion concentration

Remarkable fluctuations in pH were observed in the retting zone, from the alkaline to acidic phase and this was influenced by the rainfall. The lowest pH of 4.2 in the retting zone was recorded immediately after the heaviest rains of the year. Such a variation accompanying rainfall were reported by Ibert and Hood (1963) and Riley and Skirrow (1965). In the non-retting zone, the highest pH occurred at the peak of the south-west monsoon season. This region being the direct recipient of river discharge and exchange from the adjacent sea, almost always maintained high pH values when compared to the retting zone.

Nutrients

The present data on phosphate and nitrate is the first detailed report from the retting zones of the Kerala backwaters. The concentrations of phosphate were significantly higher at the retting zone during the pre-monsoon and monsoon periods. Complete depletion of phosphate was more common at the non-retting zone. The present study has revealed an interesting relationship between phosphate and oxygen concentrations in the retting zone. This is peculiar in the context of the retting zone hydrography. Higher values for phosphate occurred when there were total depletion of oxygen. Similarly depletion of phosphate coincided with relatively high values for oxygen. A positive correlation has been found between phosphate and hydrogen sulphide suggesting that high phosphate content was accompanied by high concentrations of hydrogen sulphide. The retting zone, in fact resembles the stagnant Norwegian Fjords of Strom (1936) with regard to hydrogen sulphide and phosphate.

The depletion of nitrate at the non-retting zone generally synchronised with the same condition at the retting zone. Their upward and downward fluctuations also were similar, the highest concentration at both the stations occurred in the monsoon season. The mean nitrate content was lower at the retting zone during the pre-monsoon and monsoon seasons than the corresponding values at the non-retting zone. The high values of nitrate after the rains amply testify the noticeable impact of the rains and river discharge over its variations. The Korapuzha estuary (Rao and George, 1959), Cochin estuary (Sreedharan and Salih, 1974) and the Ashtamudy estuary (Rajan, 1972) depicted such a trend with rain fall.

According to Corner and Davis (1971) and Kaushik and Robinson (1976) denitrification is the most important event resulting in the depletion of nitrate. The retting zone nitrate depletion is induced by a denitrification process initiated by bacteria, in the absence of dissolved oxygen. Broad areas of the Pacific and Indian oceans, the Arabian sea, the Cariaco Trench and the Black sea are reported to have experienced similar conditions when the oxygen concentration falls below a critical level or when it approached zero values (Vaccaro, 1967).

Fauna of the Retting Zone in Relation to Hydrogen Sulphide and Deficiency of Oxygen

The studies on the fauna of the retting zone have revealed the existence of a highly diverse invertebrate fauna in the sulphide biome comprising the floor and the entire water column lying over it represented by both benthic and planktonic organisms.

Zooplankton

In the plankton, the largest group was crustaceans represented by *Acartiella gravelyi* and *Acartia plumosa* of the calanus group ; *Oithona plumifera* of the cyclopoid group ; *Euterpina acutifrons* of the harpacticoid group and *Evadne tergestina, Penilia avirostris* and *Podon* sp. of the Branchiopoda. However, the calanoid copepods formed the largest group of crustaceans in the sulphide biome. Branchiopods were very few. Phylum insecta also contributed substantially to the fauna of this biome. *Chironemus* larvae and *Culex* larvae were the dominant groups. Other groups that had a sizeable representation in the plankton of the sulphide biome were nematodes and rotifers. Polychaetes, decapod larvae, molluscs and fish larvae were negligible. When the molluscs and fish larvae occurred in the samples. The surface waters were completely devoid of hydrogen sulphide only once during the entire period of study when molluscs and fish larvae also occurred only on this sample.

Benthos

The benthos of the sulphide biome was composed of nematodes like *Desmodora* sp., *Sabatiera intermissa* and *Dorylaimus* sp. Oligochaetes of the genera *Enchytraeus* and *Pontodrilus., polychaetes* like *Pisione gopalai, P. complexa, Sabella* sp. and *Nereis* sp., harpacticoid copepods like *Arenosetella indica* and *Paramesochra wilsoni* ; amphipods like *Quadrivisio bengalensis, Orchestia platensis, Parorchestia notabilis* and *Corophium triaenonyx* ; tanaids like *Apseudes* and *Tanais* ; insects like *Chironemus* larvae and a few molluscs. Of all the benthos *Desmodora* sp., *Sabatiera intermissa, Dorylaimus* sp., oligochaetes, *Arenosetella indica* and *Paramesochra wilsoni* are highly specific to the retting zone. They did not occur in the non-retting zone.

Comparison with other sulphide systems

The exciting revelations of Fenchel and Riedl (1970) have evoked a wave of enthusiasm all over the world to study the curious habits of the fauna of the oxygen deficient sulphide biomes. This has also revived interest in questions of anaerobiosis in lower metozoa (Ott and Schiemer, 1973).

The investigations in the retting zone have recorded nematodes and oligochaetes in fairly good numbers. There are three species of nematodes and two genera of oligochaetes. Compared to the population densities in the Scandinavian waters they were considerably small in the retting zone sulphide biome. Gastrotrichs present in the Scandinavian waters were not found in the retting zone although they were present in the adjoining non-retting zone. While Arthropods, were conspicuous by their absence in the collections of Fenchel and Riedl(1970), this group constituted largest group of metazoans present in the sulphide biome of the retting zone. The group was represented by several species of planktonic and benthic copepods particularly harpacticoids, amphipods, tanaids and decapods. The crustaceans were the biggest component of arthropods. Insects also formed an important component in the sulphide biome represented mainly by Culex and *Chironomus* larvae in the plankton and *Chironomus* larvae alone in the benthos. While the living system of the sulphide biome described by Fenchel and Riedl (1970) contained organisms belonging to the primarily unicellular category and a few metazoan group, the present observation from the retting zone was restricted to the metazoan group whose diversity was higher than the sulphide biome of Fenchel and Riedl (1970). It also gives a comparison between a temperate marine environment and a tropical, brackish water, polluted backwater.

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LEACHING OF SOIL FROM THE BUNDS AS A FACTOR RESPONSIBLE FOR THE LOWERING OF pH OF WATER IN BRACKISHWATER PONDS

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ABSTRACT

Heavy mortality of prawns viz. *Penaeus monodon, Metapenaeus monoceros* and *M.dobsoni* and fish *Mugil dussumieri* was observed in the Fish Farm at Vyttila, Cochin during the first heavy monsoon rains. The pH of water in these ponds was found to have dropped from 7 to 4.5. The lowering of water pH is attributed to the leaching of soil from the bunds during the first heavy rains. In experiments conducted in the laboratory, the pH of the pond water was found to drop from 7 to 4.5 when 200 ml of leachate from 100 gms of top soil was added to 1.8 litres of pond water.

Application of lime at a dose of 100 kg/ha. together with exchange of water was found to help in improving the pH of pond water to the extent of 0.6 pH unit in one day avoiding further mortality of prawns. In the laboratory experiments also the pH of pond water was found to increase to the extent of 0.45 pH unit when lime was applied at a dose of 40 ppm. Application of lime is suggested as a method for improving the pH in case of sudden drop of pH causing mortality of prawns and fishes.

INTRODUCTION

IT IS estimated that nearly 86,900 ha. of brackishwater area are available in Kerala State, suitable for fish and prawn culture (KAU publication, 1978). In many places of this area especially in Ernakulam District, ponds and low lying fields are utilized for fish culture. The physico-chemical properties of water in these areas change throughout the year. Salinity drops sharply and water becomes almost fresh during monsoon season (May-October). Salinity reaches its maximum in April-May period. Water pH also changes according to season. Drop in pH and mortality of fish such as *Mugil dussumieri* and prawns such as *Penaeus monodon, Metapenaeus monoceros* and *M. dobsoni* associated with this drop are observed in the beginning of intense rains in the brackishwater ponds at Vyttila during 1978 and 1979. The soil in brackishwater areas of this region is highly acidic and saline in nature (Money and Sukumaran, 1973). In certain parts of Ernakulam and Alleppey districts very sharp fall in pH of water below 4.5 followed by fish mortality was noticed during the heavy rains (May-July) in newly constructed ponds. It was observed that salt crust formed on the surface of pond bunds during the summer season get washed into the ponds during rainy season in large quantities. The drop in pH was found to be minimum in ponds having turfed bunds. Banerjea (1967) had stated that water pH is one of the deciding factors of fish production.

These observations prompted a preliminary study of the effect of soil leaching on pH of brackishwater fish culture ponds.

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Materials and Methods

Two brackishwater ponds in Vyttila of Ernakulam District were used for the field observations in the present study. The first pond (A) has a large area of exposed soil bunds. The other (B) has its bunds covered with grass and laterite with only very little exposed area. Water has a depth of about 0.75 metre. Water exchange was given in both the ponds at least once in a week from a common feeding canal which in turn opens into backwater having a tidal amplitude of about 60 cm. pH was determined regularly for one year from January to December 1978 by electrometric method.

Leachate was prepared by extraction of top soils of the bunds having moderate content of salt with distilled water in the ratio 1 : 2 by weight. This solution was filtered through whatman No. 42 filter paper and used for studying pH drop.

Water from the two ponds was collected at the critical time, *i.e.* just before the intense rain and mixed in equal proportion. 2 ltr. of this water was taken in each of 4 glass jars. To these, soil extract was added to the extent of 2.5%, 5%, 10.0% and 12.5%, 5%, 10% and 12.5%. A set of duplicate and a blank were also kept. pH of each sample was recorded at one hour interval continuously for 6 hours using a digital pH meter.

To study the effect of lime in improving the pH, different quantities of commercially available lime was added in three different proportions to water samples having pH 4.5-lowered by adding required quantity of soil extract to the pond water — to the extent of 20 ppm, 30 ppm and 40 ppm. pH before and after adding lime was followed using a pH meter. Chemical analysis of soil extract and pond water was carried out as per standard methods (APHA, 1971).

Results

The monthly variations of pH of the water of the two ponds A and B are presented in Fig. 1. pH of the ponds in summer months is between 7 and 8. In pond A the pH decreased very sharply from 7.0 to 4.5, during intense rain in May. In pond B, with minimum exposed soil in the bunds, the minimum pH recorded was 6. In both the ponds pH started raising from August onwards. The lowest pH in the feeder canal and rain water was 6.2 throughout the monsoon season. The higher pH observed in feeder canal water may be due to the higher tidal effect. When commercially available lime was added in pond A at a dose of 100 Kg/ha together with water exchange for one day, the pH was found to rise from 4.5 to 5.1.

There was heavy mortality of the fish *Mugil dissumieri* stocked in pond A associated with the drop in pH. In pond B having pH 6, where also *Mugil dussumieri* was stocked during the period, there was no mortality.

The data of the laboratory experiment for showing the effect of addition of soil extract on water pH, are given in Table 1. The results show that addition of 10% of the soil extract, (*i.e.* 200 ml soil extract added to 1.8 litre of pond water) alone can cause a drop in pH from 7 to 4.5.

The estimated concentrations of dissolved constituents in the soil extract and the pond water along with that of the sea water are given

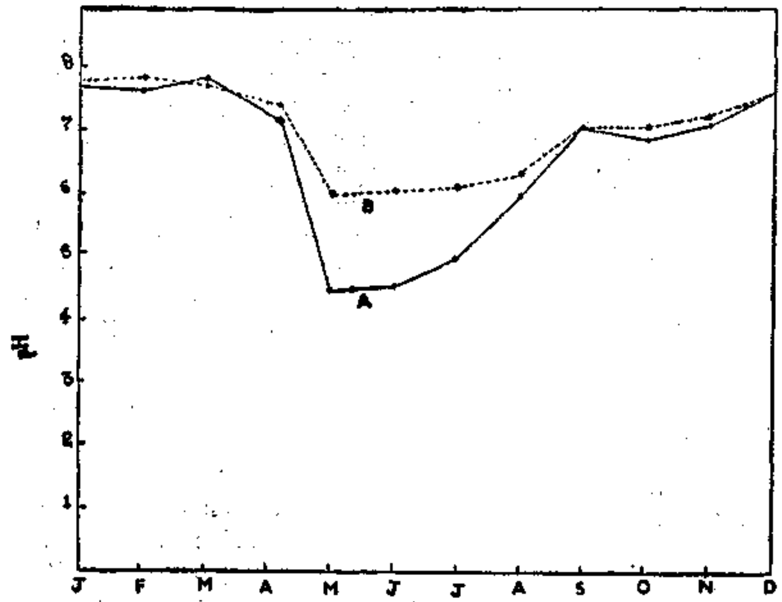

Fig. 1. Monthly variation of pH in pond A with large area of exposed soil bund and pond B with very little exposed area.

TABLE 1. *Change of pH of pond water with the addition of soil extract*

Quantity of pond water in Litres		Quantity of soil extract ml	Percentage of soil extract added (%)	pH
2	..	Nil	0	(Blank) 7.02
1.95	..	50	2.5	6.45
1.90	..	100	5	5.06
1.80	..	200	10	4.51
1.75	..	250	12.5	4.32

in Table 2. It shows that the soil extract is highly acidic and the top soil of the pond bunds is having high content of soluble salts. The predominating anions are chlorides and sulphates. The ratio of alkali metals to anions was low compared to that of the sea water.

The changes brought about in the pH of pond water by addition of different quantities of lime, under laboratory condition are given in the Table 3. It was observed that liming to the extent of 40 ppm can raise the water pH by 0.45 unit from 4.5.

TABLE 2. *Estimated concentrations of dissolved constituents in soil extract and pond water with corresponding values for sea water (Salinity 35°/₀₀)*

		Soil extract %	Pond water %	Sea water* %
Total Soluble Solids	..	12.150	0.44	3.5
Sodium	..	2.06	0.088	1.077
Potassium	..	0.02	0.0049	0.0399
Magnesium	..	0.204	0.004	0.1294
Calcium	..	0.105	0.006	0.0412
Aluminium	..	0.0018	Trace	—
Iron	..	0.0048	N.D.	Less than 0.01 ppm.
Chloride	..	7.116	0.2056	1.934
Sulphate	..	2.220	0.031	0.2712
Bicarbonate	..	—	0.0095	0.014
pH	..	3.0	7.02	—

* Source : Burton and Liss (1976).

TABLE 3. *Changes in pH on addition of lime to the pond water-Soil extract mixture*

Quantity of lime added (in ppm)	Initial pH	Final pH	Difference pH Unit
20	4.51	4.64	0.13
30	4.50	4.83	0.33
40	4.51	4.96	0.45

Discussion

The results of analysis of soil extract show that the surface soil is highly saline and soluble salt content is more than three times that of sea water having a salinity of 35‰. This may be due to the salt crust formed on the surface by crystalisation of soluble salts uplifted through capillary action in summer months.

The pH of 1 : 2 soil extract is found to be 3, indicating the presence of soluble acidic materials in the soil. The high acidity of the soil in brackishwater areas of Kerala is attributed to the presence of free mineral acids such as sulphuric and hydrochloric acids and their salts (Money and Sukumaran, 1973). Acid salts of Iron, Aluminium, Magnesium, Calcium are formed in soil in the presence of the above acids. The high content of chlorides and sulphates in the soil extract supports this view.

The results of laboratory experiments show that addition of 10% of the soil extract prepared from the top soil of the bund, with medium content of salt, to the pond water, alone can cause a drop in pH from 7 to 4.5. Similar sharp drop in pH is observed in the culture pond. This can be attributed to the introduction of free acids or acidic salts from the bund into the ponds by leaching of soil during intense rainy season. The buffering capacity is lowered by the introduction of rain water. These changes are augmented with the start of heavy monsoon rains. A sudden change in the acid-base balance and introduction of acidic substances by way of soil leaching into the ponds may cause a sharp drop in pH. Katsumi *et al.* (1978) suggest similar mechanism to explain the effect of acid mine drainage in reducing the pH of lake Toya, of Japan. Lowering of pH in brackishwater ponds to a limited extent, as seen in pond B, is possible when saline phase is changed into fresh water phase during monsoon season. The bacterial fermentation and other organic decaying processes may also have partial contribution in bringing about the pH drop. The sudden drop in pH to such a low level of 4.5 can lead to mass mortality of fishes and prawns. Several authors reported mortality of fish and other untoward effects at low pH (Beamish and Harvey, 1972; Jenson and Snekvik, 1972).

In the laboratory experiment addition of commercial lime to an extent of 40 ppm was found to help to raise the pH by 0.45 unit from 4.5. The action of lime can be neutralization of acids and acid salts. It can improve the buffering capacity of pond water. Lime may help in improving light penetration by precipitation of coloured humic substances. In the field the rise in pH can be attributed mainly to the action of lime since the water exchange achieved in a day is limited. Application of lime to the pond in limited quantities can be adopted as a measure to improve the water pH in case of sudden drop thereby preventing mass mortality of fishes and prawns. Providing turf, growing creepers and spreading sand on the pond bunds and mixing up of lime with top soil of the bunds also may help to prevent the formation of acidic salt crust on the bund surface and their leaching into the ponds.

It is suggested that the amount of soil leachate that will cause a pH drop to detrimental level and the extent of pH drop depend on the chemical nature and other conditions of the soil on the bund and water in the ponds. Further studies are required to find out quantitative relation between the pH and chemical changes in ponds brought about by soil leaching.

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UTILITY OF OOCYTE STAGES IN GONAD INDEX DETERMINATIONS

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ABSTRACT

The gonad index method is extensively employed for the determination of reproductive activities of fishes and shell-fishes. However, the gonad index alone is ineffective in providing detailed information on the exact condition of oocytes in the ovary. Hence detailed studies on the maturation process of the ovary of the hermit-crab *Clibanarius clibanarius* were undertaken along with microscopic examination of gonad structure. Three main stages of ovary based on oocyte diameters were recognised during maturation of this crab and month-wise percentage of each stage in the population was plotted against each mean gonad index value. The emerging picture indicated that the gonad index was influenced by ovaries with stage-3 oocytes and an increase in the latter could substantially raise the gonad index.

INTRODUCTION

AMONG the various methods used in the past for the study of the reproductive cycles in marine invertebrates (Subrahmanyam, 1963) the gonad index (G.I.) method initiated by Giese (1959) has been the most widely used one. The G.I. plotted against time, however, provides only an overall picture of the probable state of the ovary during the different months of the year. Thus higher indices may indicate imminent spawning while lower ones may point to either a spawned out gonad or the one in the resting phase (Giese, 1959 ; Pillay and Nair, 1971). So the actual stage of the oocyte that contributes to the rise and fall of G.I. in a protracted study period is not provided. Further, the ovary may as in echinoderms, contain nutritive cells, nutritive phagocytes and follicle cells (Giese and Pearse, 1974) and fluctuation in these may mask the true gonad-animal relationship. For this purpose, during reproductive cycle studies on a hermit crab *Clibanarius clibanarius*, data on oocyte stages were scrutinised in concert with those of gonad indices.

MATERIAL AND METHODS

The hermit crabs *Clibanarius clibanarius* (Dana) were collected from launches operating in the offshore waters of Madras upto a depth of 10 fathoms. The animals were brought to the laboratory, removed from their shells, wiped dry and weighed in a monopan electric balance to the nearest tenth of a milligram. Only undamaged females in the intermoult stages recognised as such by Drach (1939) were used in these studies. The animals were dissected, microscopic examination of the ovaries were made and the latter weighed. The G.I. was calculated using the formula $\frac{\text{Gonad wt.}}{\text{Animal wt.}} \times 100$ (Giese, 1959). The diameters of oocytes were measured using the ocular micrometer and the overall colour of the ovary was noted.

RESULTS

Microscopic examination of oocytes and the colour of ovaries were utilised in staging ovarian development. It has been shown that in a brachyuran decapod ovary such as that of *Carcinus maenas*, oocytes are transformed from premeiosis to vitellogenic stages, not *en masse* but in successive waves (Laulier and Demeusy, 1974). In the case of *Clibanarius clibanarius* except in the earliest stage when the entire, flaccid ovary is dominated by the germinal zone, a regular gradation of oocytes is evident in a single cross section (Varadarajan and Subramoniam—in preparation). Ovaries were therefore assigned to the stage into which the majority of the oocytes could be fitted into. meters between 150-379 μm were assigned to stage 2 when discrete yolk droplets appeared within them and their colour ranged from yellow to orange. Oocytes with diameter 380 μ - 540 μm or above were in stage 3 when they were almost ripe or fully ripe imparting a deep brown colour to the ovary and ooplasm filled with yolk globules. The percentage composition of each of these three stages in the population within a month was noted. Histograms of such compositions were aligned with corresponding monthly gonad index (Fig. 1).

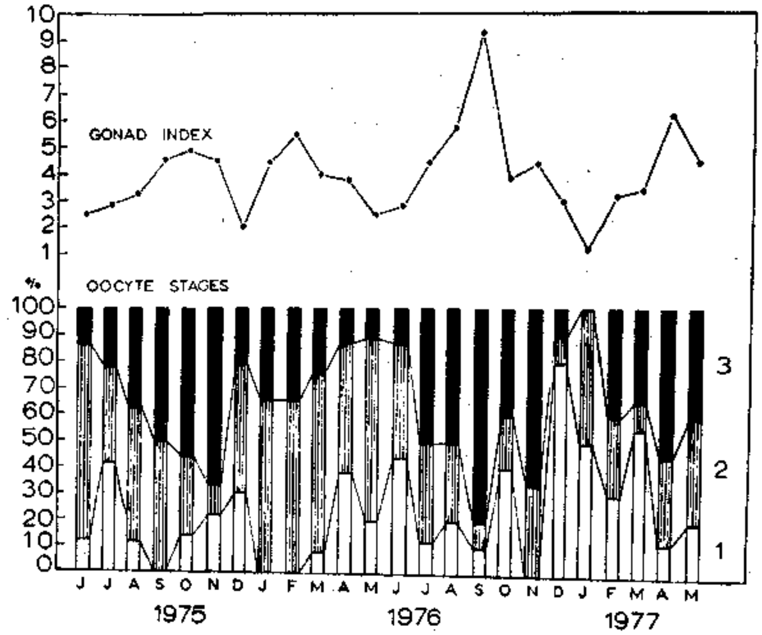

Fig. 1

Ovarian colour was another criterion used to classify the stages. Criteria used by previous crustacean investigators for staging oocytes are gross appearance and dimensions of ovary, colour, oocyte diameter and oocyte volume.

In the present study three different stages were recognised for *C. clibanarius* on the basis of diameter, colour and the presence of yolk. Those with diameters upto 149 μm with no yolk were classified as stage 1, the colour being whitish or pale yellow. Oocytes with dia- Thus the mean-gonad index in every month was further broken down to provide an insight into the actual condition of oocytes in that population.

Discussion

The reproductive cycle of *Clibanarius clibanarius* as envisaged by the mean of G.I. is seen to be an almost uninterrupted one during the two year period of investigation. On closer scrutiny, however, breeding is not without a pattern. G.I. rises to a second maximum the following February (Fig. 1). If the second half of the study period is considered (June 1976, May 1977) two peaks are again evident although the first is a month ahead and the 2nd two months later, compared to the previous year. The peaks and lows are shallower for the first year while a higher peak in 1976-77, is offset by a steaper G.I. fall for that year (Fig. 1). The non-coincidence of data in successive years due to shifts in reproductive activities was already pointed out by Giese (1959) for marine invertebrates in general and by Turoboyski (1973) in *Rithropanopeus harrisii* in particular and attributed this to hydrographical, meteorological and thermal conditions which vary in a place from year to year. The rise and fall in G.I. could be clearly explained by the percentage of oocyte stages. The peak G.I. for the study period was in September 1976, which coincided with a population in which stage 3 oocytes predominate. The peak in the second year being higher than that in the first year, is likewise the result of more animals with ripe ovaries in the former. As a corollary, the lowest G.I. coincides with a population in which crabs have no ripe ovaries.

Again G.I. values can be made to yield another kind of information when oocyte-diameters (which in fact contribute to the stages) are considered. Varying G.I. need not always be due to varying percentage of ripe-ovaried forms in the population. Rarely (January and February, 1956), the same population of maturing and mature animals are present, but oocyte diameters are greater in February contributing to a higher ovary/animal ratio (Varadarajan, 1978). So ripe ovaries with larger oocytes induce G.I. to rise. Seasonal variations in oocyte-diameters have been noted in *C. olivacious* (Subrahmanyam, 1935) but these have not been correlated to G.I. values. Lack of stage-I oocytes in these months again confirm that no spawning takes place. Actually berried females were numerous in the three subsequent months as revealed from percentage of ovigerous females (Varadarajan, 1978).

Equal G.I. in different months may not always reflect similar ovarian states. For instance, in September and November 1975, the G.I. value is 4.63 ; yet no stage-I ovaries are present in September and the population consists of maturing and mature females alone. But in November, 10% of them have stage-I oocyte-composition. This indicates spawning of a section of the population and this act continues till December when G.I. drops to its lowest value (2.4) for that year and 35% of the population have already spawned. While the G.I. provides a generalised picture of ovarian activity, oocyte compositions provide details that elucidate and complement G.I. values.

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PRODUCTION FUNCTIONS IN FISHERY RESEARCH

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ABSTRACT

Assessment of aquaproduction assumes all the more importance, at present, as there is global awareness to add more to food supply from water resources by husbanding wild fishery resources. This assessment demands the determination of carrying capacity of water bodies both qualitatively and quantitatively. Here in this paper quantitative approach is touched.

Models developed on the basis of some assumptions on growth, mortality etc. are available. Ricker (1946) and Allen (1950) developed a model to quantify the production by $P = GB$ where G is the instantaneous growth rate and B is the average biomass during the period of reference. Similarly Gulin and Rudenko (1973) also gave a model giving production by $P_t = a_t N_t (1-e^{-zt})/zt$. Similar models can be evolved with varying assumptions.

To find out the differential potentialities of water bodies, error estimates for production functions are required for comparing production of different water bodies and to see whether the differences if any are due to any assignable causes or not. Many models suffer for want of such methods to estimate errors associated with the production functions. Method to estimate error for the model developed by Gulin and Rudenko (1973) is not available. Chapman (1971), however, has tried to find out an error estimate for Ricker's model. In that it is assumed that correlation between G_t and B_t is negative and ommitted.

In this paper various production functions are evaluated and derived complete expressions for their variances leading to their error estimates. The conjecture posed by Chapman (1971) about the negativity and negligibility of the correlation between $\hat{\bar{B}}_t$ and $\hat{G}_t$ is studied and proved that correlation $\hat{B}_t$ and $\hat{G}_t$ is negative whereas that between average $\hat{B}_t$ namely $\hat{\bar{B}}_t$ and $\hat{G}_t$ nothing could be stated. And also this part of variance, namely the covariance between $\hat{G}_t$ and $\hat{\bar{B}}_t$ is accounted for in this paper as this may not be negligible thus giving full expression to the variance function for Ricker's model.

Among different types of models, one based on liner relationship on numbers over time and growth over time is suggested for its simplicity, theoretical soundness and practical applicability. An example is considered and estimates compared along with their variance estimates.

INTRODUCTION

CULTURE practices in confined waters have recently taken great strides in developing as well as developed countries. To determine carrying capacity of a water body it is necessary to evaluate its production. In general, production is not synonymous with yield. To determine production, periodical observations on number and average weight of population are required. Since feeding schedules depend on number of animals and their average weight, such periodical samplings are of much help. Apart from this, difference between production and yield may throw light on factors such as mortality that are responsible for the difference and that may suggest the ways to improve yield. Moreover periodical sampling leads to estimates of vital rates and study of growth under different feeding schedules.

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Following Ricker (1971) production can be defined as the increase in biomass in a given time including the growth of those which die or which are caught during this interval. On the basis of this, Ricker (1946) and Allen (1950) have found the production function

$$P = G\bar{B} \quad \ldots \quad \ldots \quad \ldots \quad (1)$$

where P is the production, G the instantaneous growth rate in weight and $\bar{B}$ the average biomass during the period of reference. It is assumed here that G does not vary during this period and that growth in weight follows exponential law with time viz :

$W = W_o \ e^{Gt}$ whereas change in numbers may follow any law. Beverton and Holt (1957) have evaluated production function on the assumption that growth in weight follows von Bertalanffy's model and change in numbers follows exponential law with time resulting in

$$P = RW_\infty \sum_{n=0}^{3} \Omega_n \ e^{-nK(t_\rho - t_0)} \frac{1 - e^{-(F+M+nK)(t_\lambda - t_\rho)}}{F+M+nK} \quad (2)$$

Recently Gulin and Rudenko (1973) have estimated production of lake Demenets by using

$$P_t = a_t \ N_t \ (1 - e^{-Z_t})/Z_t \quad (3)$$

assuming that growth in weight is linear and change in numbers is exponential with time where

$$N_t \ (\tau) = N_t \ e^{-Z_t \tau}$$

and

$$W_t \ (\tau) = W_t + a_t \ \tau$$

where t is the age of fish, τ any instant in (0, 1). Here the instantaneous mortality rate Z_t etc. is age specific.

Chapman (1971) has given variance function for (1). However, explicit variance function for (3) is not available. Even in case of (1) Chapman (1971) has not given the complete expression for variance function. In this case the contribution from covariance of $\hat{G}_t$ and $\hat{\bar{B}}_t$ is omitted with a remark that correlation between $\hat{G}_t$ and $\hat{B}_t$ as expected, may be negative. The variance function thus arrived at by him is

$$V(\hat{P}_t) = G_t^2 \ V(\hat{\bar{B}}_t) + \bar{B}_t^2 \ V(\hat{G}_t)$$

To estimate $V(\hat{G}_t)$ he also suggests to take few subsamples leading to few estimates of G_t and from these estimates he gets $\hat{V}(\hat{G}_t) =$

$$\left[\Sigma \ G_t^2 - \frac{(\Sigma \ G_t)^2}{r}\right] \Big/ (r-1)$$

where 'r' is the number of subsamples.

In this paper we shall derive complete expressions for variance functions of different production functions. We shall prove that correlation between $\hat{B}_t$ and $\hat{G}_t$ is negative whereas nothing can be said with certainty about the sign of correlation between B_t and G_t. We shall also take an estimate of $V(G_t)$ from the large sample theory avoiding subsampling approach suggested by Chapman (1971). Finally we shall consider an example taken from Chapman (1971) and see how estimates and their variances obtained from different production functions compare.

Production Functions

Starting from the definition, in the usual notation we have $dP_t = N_t dW_t$. Assuming without loss of generality that the entire period is divided into unit segments each segment representing a month or a season or a year as the case may be, we may write.

$$P_t = \int_0^1 N_t(T)\, dW_t(T);\ (0 < T < 1) \qquad (4)$$

where P_t is the production in $(t, t+1)$ segment. Basing on (4) we shall get different production functions under different assumptions and note down those which are already available in the literature.

Assumption I

$$N_t(T) = N_t\, e^{-Z_t T}$$

and

$$\bar{W}_t(T) = \bar{W}_t\, e^{G_t T}$$

then

$$P_{1t} = \frac{N_t \bar{W}_t G_t}{(G_t - Z_t)}\, [e^{(G_t - Z_t)} - 1] \qquad (5)$$

when $G_t > Z_t$

$$= \frac{N_t \bar{W}_t G_t}{(Z_t - G_t)}\, [e^{(Z_t - G_t)} - 1] \qquad (6)$$

when $Z_t > G_t$

$$= N_t W_t G_t \quad \text{when } Z_t = G_t \qquad (7)$$

It may be noted that whenever $|G_t - Z_t|$ is sufficiently small such that $N_t \bar{W}_t G_t\, |G_t - Z_t|$ becomes negligible then (5) and (6) lead to (7). Forms (5) and (6) have been dealt with by Ricker 1971 and Allen 1950 and considered by Chapman 1971.

Assumption II

$$\bar{W}_t(T) = \bar{W}_t\, e^{G_t T}$$

and no assumption be made on N_t. Then

$$P_{2t} = \int_0^1 G_t N_t(T) \bar{W}_t(T)\, dT$$

$$= G_t \int_0^1 B_t(T)\, dT$$

$$= G_t \bar{B}_t \qquad (8)$$

where $B_t(T)$ is the biomass of fish of age 't' at T th instant and $\bar{B}_t$ is the average biomass of fish of age 't' in $(t, t+1)$ segment. (8) has been derived by both Ricker (1971) and Allen (1950).

Assumption III

$$N_t(T) = N_t\, e^{-Z_t T}$$

and no assumption be made on W_t, then

$$P_{3t} = \int_0^1 N_t(T)\, d\bar{W}_t(T)$$

$$= [N_t(T)\bar{W}_t(T)]_0^1 - \int_0^1 \bar{W}_t(T)\, dN_t(T)$$

$$= N_{t+1}\bar{W}_{t+1} - N_t \bar{W}_t + Z_t \int_0^1 \bar{W}_t(T) N_t(T)\, dT$$

$$= B_{t+1} - B_t + Z_t \bar{B}_t \qquad (9)$$

Assumption IV

In any curve, when sufficiently segmented, each segment may satisfactorily be approximated by a straight line. Hence let us assume $N_t(T) = a_{1t} + b_{1t} T$

and

$$\bar{W}_t(T) = a_{2t} + b_{2t} T$$

in the usual notation. Then

$$P_{4t} = b_{2t}\, [a_{1t} + b_{1t}/2] \qquad (10)$$

Assumption V

$N_t(T) = a_{1t} + b_{1t}T$

and

$\bar{W}_t(T) = \bar{W}_t\, eG_t\, T$

Then

$$P_{5t} = B_{t+1} - B_t - \frac{b_{1t}\bar{W}_t}{G_t}[eG_t - 1] \quad (11)$$

$$= B_t T^1 - B_t - b_{1t}\bar{W}_t \quad (12)$$

When $b_{1t}\,\bar{W}_t\,G_t$ is negligible.

Assumption VI

$N_t(T) = N_t\, e^{-Z_t T}$

and

$\bar{W}_t(T) = a_{2t} + b_{2t}T$

Then

$$P_{6t} = N_t\, b_{2t}\,[1 - e^{-Z_t}] / Z_t \quad (13)$$

$$= N_t\, b_{2t} \quad (14)$$

when $N_t\, b_2\, Z_t$ is negligible. The form (13) has been considered by Gulin and Rudenko (1973).

Assumption VII

$N_t(T) = a_{1t} + b_{1t}T$

and no assumption be made on $\bar{W}_t$. Then

$$P_{7t} = B_{t+1} - B_t - b_{1t}\,\bar{\bar{W}}_t \quad (15)$$

where $\bar{\bar{W}}_t$ is the mean of $\bar{W}_t$ in $(t, t+1)$.

Assumption VIII

$\bar{W}_t(T) = a_{2t} + b_{2t}T$

and no assumption be made on N_t. Then

$$P_{8t} = b_{2t}\,\bar{N}_t \quad (16)$$

Here it may be noted that if $\bar{N}_t$ is estimated from a simple average $(N_t + N_{t+1})/2$ and $\bar{W}_t$ from $(\bar{W}_t + \bar{W}_{t+1})/2$ then P_{4t}, P_{7t} and P_{8t} are one and the same. Normally $\bar{N}_t$ is estimated from the average of N_t and N_{t+1}. Similarly $\bar{W}_t$. As such for all practical purposes P_{4t}, P_{7t} and P_{8t} are not different.

Assumption IX: von Bertalanffy's model.

Case i : Growth is isometric.

$$W_t = W_\infty\,[1 - e^{-K(t - t_0)}]^3$$

and $N_t = N_0\, e^{-Z_t}$

Then the production function is of the form (2).

Case ii : Growth is allometric.

and $W_t = W_\infty\,[1 - e^{-Kd(t - t_0)}]^{n/d}$

$$N_t = N_0\, e^{-Z_t}$$

where $d = n - m$ and m is the exponent obtained in the relationship of length and surface area of fish as defined by von Bertalanffy. Similarly n is the exponent derived in the relationship between length and weight of fish (Taylor, 1962). In this case

$$P_t = C\int_{x_2}^{x_1} x^{p-1}\,(1-x)^{q-1}\,dx \quad (17)$$

where t_r is the age of fish beyond which fish are not available for catch;

$$C = (R'/d)n\, W_\infty\, e^{(F+M)\,(t_{\rho 1} - t_0)};$$

$$x_1 = e^{-Kd(t_{p1} - t_0)}$$

$$x_2 = e^{-Kd\,(t_\lambda - t_0)}.$$

Other symbols have the same connotation as in (2). Now (17) is an incomplete beta function which can be evaluated.

No doubt, by assuming different forms for W_t and N_t with 't' many such production functions can be evaluated. However, the assumptions on which the above production functions are based, almost cover the growth forms in currency in fishery research. By empirical studies if some other functions are found to be fitting better, then on the basis of such arrived at functions of W_t and N_t production functions can be found out.

Estimation of production

To estimate production, using the above production functions, we require estimates for N_t, W_t, G_t, Z_t etc. This we shall see in this section.

For estimation of N_t vast literature is available. Seber (1973), Robson and Regier (1964) and others have dealt with this problem. From these methods any appropriate method of estimation may be chosen and N_t estimated. From the sample or subsample taken for estimation of N_t corresponding observations on weight will give an estimate for $\bar{W}_t$. However, independent samples for estimating N_t and $\bar{W}_t$ would simplify the variance estimates. Hence throughout this paper it is assumed that estimates on N_t and $\bar{W}_t$ are obtained independently so that their covariance term vanishes. Now

$$\hat{G}_t = \log_e \hat{\bar{W}}_{t+1} - \log_e \hat{\bar{W}}_t \quad (18)$$

since we are considering unit time segments. Similarly

$$\hat{Z}_t = \log_e \hat{N}_t - \log_e \hat{N}_{t+1} \quad (19)$$

$$\hat{B}_t = \hat{N}_t \hat{\bar{W}}_t \quad (20)$$

$$\hat{\bar{B}}_t = (\hat{B}_{t+1} + \hat{B}_t)/2 \text{ and } \hat{\bar{N}}_t = (\hat{N}_{t+1} + \hat{N}_t)/2$$

Using the above estimates P_{1t} to P_{3t} can be found out.

Then for P_{4t} to P_{8t} we have $\hat{a}_{1t} = \hat{N}_t$ $\hat{b}_{1t} = \hat{N}_{t+1} - \hat{N}_t$; $\hat{a}_{2t} = \hat{\bar{W}}_t$ and $\hat{b}_{2t} = \hat{\bar{W}}_{t+1} - \hat{\bar{W}}_t$. Thus all functions P_{1t} to P_{8t} can be estimated. For the rest we require estimates of F, M, K, t, t_0 etc. Beverton and Holt (1957), Paulik and Gales (1964) etc. have given methods to estimate these parameters. Since we are dealing with culture aspects these estimates are not considered in this paper.

Variance functions

Many biological functions suffer for want of corresponding variance functions. In this section let us find out variance functions for some production functions evaluated above. In doing so we shall have minimum assumptions so that variance functions evaluated on the basis of these assumptions do not differ much from their exact counterparts.

The estimate $\hat{V}(\hat{N})$ depends on the procedure by which N is obtained and $\hat{V}(\hat{N})$ is readily available from Seber (1973) and others.

Now

$$\hat{V}(\hat{\bar{W}}_t) = \hat{V}(\hat{W}_t)/r$$

and

$$\hat{V}(\hat{W}_t) = [\Sigma W^2_{ti} - (\Sigma W_{ti})^2/r] / (r-1) \quad (21)$$

From Kendall and Stuart (1963)

$$\hat{V}(\log_e \hat{\bar{W}}_t) = \hat{V}(\hat{\bar{W}}_t) / \hat{\bar{W}}^2_t \quad (22)$$

Hence

$$\hat{V}(\hat{G}_t) = \hat{V}(\log_e \hat{\bar{W}}_t) + \hat{V}(\log_e \hat{\bar{W}}_{t+1})$$

$$= \frac{\hat{V}(\hat{\bar{W}}_t)}{\hat{\bar{W}}_t^2} + \frac{\hat{V}(\hat{\bar{W}}_{t+1})}{\hat{\bar{W}}^2_{t+1}} \tag{23}$$

Thus (23) avoids the recourse to subsampling to obtain $V(G_t)$ as suggested by Chapman (1971). In (23) and also hereafter, the covariance term is omitted since $\bar{W}_t$ and $\bar{W}_{t+1}$ are independently estimated. Similarly

$$\hat{V}(\hat{Z}_t) = \frac{\hat{V}(\hat{N}_t)}{\hat{N}_t^2} + \frac{\hat{V}(\hat{N}_{t+1})}{\hat{N}_{t+1}^2} \tag{24}$$

$$\hat{V}(\hat{B}_t) = [\hat{V}(\hat{B}_t) + \hat{V}(\hat{B}_{t+1})]/4 \tag{25}$$

where

$$\hat{V}(\hat{B}_t) = \hat{V}(\hat{N}_t \hat{\bar{W}}_t) = \hat{N}_t^2 \hat{V}(\hat{\bar{W}}_t) + \hat{\bar{W}}_t^2 \hat{V}(\hat{N}_t) \tag{26}$$

etc. On the basis of the above we shall evaluate here variance functions for all P_{1t} to P_{8t} except P_{5t}. Now

$$\hat{P}_{1t} = \hat{N}_t \hat{\bar{W}}_t \hat{G}_t [e^{(\hat{G}_t - \hat{Z}_t)} - 1]/(\hat{G}_t - \hat{Z}_t)$$

$$= \hat{G}_t [\hat{N}_{t+1} \hat{\bar{W}}_{t+1} - \hat{N}_t \hat{\bar{W}}_t] / (\hat{G}_t - \hat{Z}_t)$$

$$= \hat{G}_t (\hat{B}_{t+1} - \hat{B}_t) / (\hat{G}_t - \hat{Z}_t)$$

$$= N_r / D_r \text{ (say)}$$

and

$$V(P_{1t}) = \frac{V(N_r)}{D_r^2} + \frac{[E(N_r)]^2 V(D_r)}{D_r^4} - 2E(N_r)\,\mathrm{Cov}\,(N_r; D_r)\, D_r^3 \tag{27}$$

From A_1 to A_9 of the appendix

$$E(N_r) = E(\hat{B}_{t+1} \hat{G}_t) - E(\hat{B}_t \hat{G}_t)$$

$$= (B_{t+1} - B_t)\,\lambda\, G_t + \rho\,(\hat{\bar{W}}_t)\left(B_{t+1} \frac{V(\hat{\bar{W}}_{t+1})}{\bar{W}_{t+1}^2} + B_t \frac{V(\hat{\bar{W}}_t)}{\bar{W}_t^2} \right) \tag{28}$$

$$V(N_r) = G_t^2 [V(\hat{B}_{t+1}) + V(\hat{B}_t)] + (B_{t+1} - B_t)^2 V(\hat{G}_t)$$

$$+ 2(B_{t+1} - B_t)\, G_t\, \rho\, (\hat{\bar{W}}_t) \left[B_{t+1} \frac{V(\hat{\bar{W}}_{t+1})}{\bar{W}^2_{t+1}} + B_t \frac{V(\hat{\bar{W}}_t)}{\bar{W}_t^2} \right] \tag{29}$$

$$\text{Cov}(N_r, D_r) = G_t \left\{ \rho(\hat{\bar{W}}_t) \left[B_{t+1} \frac{V(\hat{\bar{W}}_{t+1})}{\bar{W}^2_{t+1}} + \frac{V(\hat{\bar{W}}_t)}{\bar{W}_t^2} B_t \right] + \rho(\hat{N}_t) \left[B_{t+1} \frac{V(\hat{N}_{t+1})}{N^2_{t+1}} + B_t \frac{V(\hat{N}_t)}{N_t^2} \right] \right\} + (B_{t+1} - B_t) \left[\frac{V(\hat{\bar{W}}_{t+1})}{\bar{W}^2_{t+1}} + \frac{V(\hat{\bar{W}}_t)}{\bar{W}_t^2} \right]$$

$$+ \rho(\hat{N}_t)\, \rho(\hat{\bar{W}}_t) \left[B_{t+1} \frac{V(\hat{N}_{t+1})}{N^2_{t+1}} \frac{V(\hat{\bar{W}}_{t+1})}{\bar{W}^2_{t+1}} - B_t \frac{V(\hat{N}_t)}{N_t^2} \frac{V(\hat{\bar{W}}_t)}{\bar{W}_t^2} \right] \tag{30}$$

where $\rho(\hat{\bar{W}}_t)$ is the correlation between $\hat{\bar{W}}_t$ and $\log_e \hat{\bar{W}}_t$ or $(\log_e \hat{\bar{W}}_t)^2$. Similarly $\rho(\hat{N}_t)$ is the correlation between $\hat{N}_t$ and $\log_e \hat{N}_t$ or $(\log_e \hat{N}_t)^2$. In this paper it is assumed that

$$\rho(\hat{\bar{W}}_t) = \rho(\hat{\bar{W}}_{t+1}) \text{ and } \rho(\hat{N}_t) = \rho(\hat{N}_{t+1}).$$

$$V(D_r) = V(\hat{G}_t) + V(\hat{Z}_t) \tag{31}$$

Using (28)—(31), $V(\hat{P}_{1t})$ can be estimated. No doubt the expression is a complex one. Similarly other functions appearing under P_{1t} can be dealt with. Now

$$\hat{P}_{2t} = \hat{G}_t \hat{\bar{B}}_t = \hat{G}_t (\hat{B}_t + \hat{B}_{t+1}) / 2.$$

Hence

$$V(\hat{P}_{2t}) = \bar{B}_t^2 V(\hat{G}_t) + G_t^2 V(\hat{\bar{B}}_t) + 2G_t \hat{\bar{B}}_t \text{ Cov}(\hat{G}_t, \hat{\bar{B}}_t) \tag{32}$$

From (A_3) of the appendix we have

$$\text{Cov}(\hat{G}_t ; \hat{B}_t) = -\rho(\hat{\bar{W}}_t)\, B_t\, V(\hat{\bar{W}}_t) / \bar{W}_t^2 \tag{33}$$

Since $\rho(\hat{\bar{W}}_t)$ is the correlation between $\hat{\bar{W}}_t$ and $\log_e \hat{\bar{W}}_t$, $\rho(\hat{\bar{W}}_t)$ is always positive. Hence we have the result that the covariance between $\hat{G}_t$ and $\hat{B}_t$ is negative. Similarly from (A_4),

$$2\,\text{Cov}(\hat{G}_t ; \hat{\bar{B}}_t) = \rho(\hat{\bar{W}}_t) \left(B_{t+1} \frac{V(\hat{\bar{W}}_{t+1})}{\bar{W}_{t+1}^2} - B_t \frac{V(\hat{\bar{W}}_t)}{\bar{W}_t^2} \right) \tag{34}$$

From (34) we cannot say with certainty about the sign of Cov $(\hat{G}_t, \hat{\bar{B}}_t)$. However, in the example considered in the end it is found (34) is negative throughout. From the above

$$V(\hat{P}_{2t}) = \bar{B}_t^2 V(\hat{G}_t) + G_t^2 V(\hat{\bar{B}}_t) + G_t \bar{B}_t \rho(\hat{\bar{W}}_t) \left(B_{t+1} \frac{V(\hat{\bar{W}}_{t+1})}{\bar{W}_{t+1}^2} - B_t \frac{V(\hat{\bar{W}}_t)}{\bar{W}_t^2} \right) \tag{35}$$

From the example it is noticed that $\rho(\hat{\bar{W}}_t)$ is almost equal to unity. As such covariance term in (35) may not be negligible as Chapman (1971) has assumed. Now $\hat{P}_{3t} = \hat{B}_{t+1} - \hat{B}_t + \hat{Z}_t \hat{\bar{B}}_t$.

Hence $V(\hat{P}_{3t}) = V(\hat{B}_{t+1} - \hat{B}_t) + V(\hat{Z}_t \hat{\bar{B}}_t) + 2\,\text{Cov}[(\hat{B}_{t+1} - \hat{B}_t) ; \hat{Z}_t \hat{\bar{B}}_t]$ (36)

From (A_5) of the appendix

$$V(\hat{Z}_t\,\hat{\bar{B}}_t)=Z_t^2\,V(\hat{\bar{B}}_t)+\bar{B}_t^2\,V(\hat{Z}_t)+\bar{B}_t\,Z_t\,\rho\,(\hat{N}_t)\left(B_t\frac{V(\hat{N}_t)}{N_t^2}-B_{t+1}\frac{V(\hat{N}_{t+1})}{N_{t+1}^2}\right) \tag{37}$$

and from (A_{10}) & (A_{11})

$$2\,\text{Cov}\,[(\hat{B}_{t+1}-\hat{B}_t)\,;\,\hat{Z}_t\,\hat{\bar{B}}_t]=Z_t\left\{B_{t+1}^2\frac{V(\hat{N}_{t+1})}{N_{t+1}^2}\,\frac{V(\hat{\bar{W}}_{t+1})}{\bar{W}_{t+1}^2}-B_t^2\frac{V(\hat{N}_t)}{N_t^2}\,\frac{V(\hat{\bar{W}}_t)}{\bar{W}_t^2}\right.$$

$$\left.+V(\hat{B}_{t+1})-V(\hat{B}_t)\right\}-\rho\,(\hat{N}_t)\left\{B_{t+1}^2\,\frac{V(\hat{N}_{t+1})}{N_{t+1}^2}\left[2\frac{V(\hat{\bar{W}}_{t+1})}{\bar{W}_{t+1}^2}+1\right]+B_t^2\frac{V(\hat{N}_t)}{N_t^2}\,.\right.$$

$$\left.\left[2\,\frac{V(\hat{\bar{W}}_t)}{\bar{W}_t^2}+1\right]+B_{t+1}\,B_t\left(\frac{V(\hat{N}_{t+1})}{N_{t+1}^2}+\frac{V(\hat{N}_t)}{N_t^2}\right)\right\} \tag{38}$$

Substituting (37) and (38) in (36), $V(\hat{P}_{5t})$ can be found out. This function is also a complex one. Now

$$\hat{P}_{4t}=\hat{P}_{7t}=\hat{P}_{8t}=(\hat{N}_t+\hat{N}_{t+1})\,(\hat{\bar{W}}_{t+1}-\hat{\bar{W}}_t)\,/\,2$$

Hence

$$V(\hat{P}_{4t})=\{\,(N_t+N_{t+1})^2\,[\,V(\hat{\bar{W}}_{t+1})+V(\hat{\bar{W}}_t)\,]+(\bar{W}_{t+1}-\bar{W}_t)^2\,[\,V(\hat{N}_t)+V(\hat{N}_{t+1})\,]\,\}\,/\,4 \tag{39}$$

Here all are known functions and $V(\hat{P}_{4t})$ is easily estimable. Finally

$$\hat{P}_{6t}=\hat{N}_t\,\hat{b}_{2t}\,(1-e^{Z_t})\,/\,\hat{Z}_t=(\hat{\bar{W}}_{t+1}-\hat{\bar{W}}_t)\,(\hat{N}_t-\hat{N}_{t+1})\,/\,\hat{Z}_t$$

Hence

$$V(\hat{P}_{6t})=V\,[\,(\hat{\bar{W}}_{t+1}-\hat{\bar{W}}_t)\,(\hat{N}_t-\hat{N}_{t+1})\,]\,/\,Z_t^2\,+$$
$$(\bar{W}_{t+1}-\bar{W}_t)^2\,(N_t-N_{t+1})^2\,V(\hat{Z}_t)\,/\,Z_t^4-$$
$$2\,(\bar{W}_{t+1}-\bar{W}_t)\,(N_t-N_{t+1})\,\text{Cov}\,[\,(\hat{\bar{W}}_{t+1}-\hat{\bar{W}}_t)\,(\hat{N}_t-\hat{N}_{t+1})\,;\,\hat{Z}_t\,]\,/\,Z_t^3$$

Only unknown term, here, is the covariance term. From (A_{12}) of the Appendix we have

$$\text{Cov}\,[\,(\hat{\bar{W}}_{t+1}-\hat{\bar{W}}_t)\,(\hat{N}_t-\hat{N}_{t+1})\,;\,\hat{Z}_t\,]=\rho\,(\hat{N}_t)\,(\bar{W}_{t+1}-\bar{W}_t)\left(\frac{V(\hat{N}_t)}{N_t}+\frac{V(\hat{N}_{t+1})}{N_{t+1}}\right) \tag{40}$$

Thus

$$V(\hat{P}_{6t})=\{\,(\bar{W}_{t+1}-\bar{W}_t)^2\,[\,V(\hat{N}_t)+V(\hat{N}_{t+1})\,]+(N_t-N_{t+1})^2\,[\,V(\hat{\bar{W}}_t)+V(\hat{\bar{W}}_{t+1})]\,\}\,/\,Z_t^2$$
$$+(\bar{W}_{t+1}-\bar{W}_t)^2\,(N_t-N_{t+1})^2\left[\frac{V(\hat{N}_t)}{N_t^2}+\frac{V(\hat{N}_{t+1})}{N_{t+1}^2}\right]/\,Z_t^4-$$
$$2\,(\bar{W}_{t+1}-\bar{W}_t)^2\,(N_t-N_{t+1})\,\rho\,(\hat{N}_t)\left[\frac{V(\hat{N}_t)}{N_t}+\frac{V(\hat{N}_{t+1})}{N_{t+1}}\right]/\,Z_t^3 \tag{41}$$

Evaluation of variance functions for the rest of the production functions is not considered in this paper as those are more complex and intractable. It may be noted that P_{4t} (P_{7t}/P_{8t}) is comfortably easier to be evaluated and so also its variance function. Moreover its variance function does not involve any term such as $\rho\,(\hat{\bar{W}}_t)$ etc. whose estimates may not be easily available. Thus in culture practices where observations are taken at short intervals production function $P_{4t}\,/\,(P_{7t}\;P_{8t})$ is the best to be considered.

Example

Now we shall take up the data given by Chapman (1971) for our analysis. Since these data contain only numbers and average weights for every month we shall proceed as follows. Let us assume that numbers are enumerated and not estimated. Hence $V(\hat{N}_t) = O$ for all 't'. To get estimates of $V(\hat{\bar{W}}_t)$ values for weight measurements are generated from random numbers as indicated below. Now $\bar{W}_t = 1.5$ g for May. Assuming that the range of W_t is in 1.0 – 2.0 g the decimal place is filled by the help of random numbers. For example the first one digit number noted from random number table was '2'. Hence the first value of W_t is 1.2. The second number from the random number tables was '0'. Hence the second value of W_t is 2.0. In this way twenty numbers are generated with the restriction that they add up to $20 \times 1.5 = 30.0$ by making slight adjustments. Thus for each month twenty values are generated with the restriction that they have the mean given by Chapman (1971). From these values given in Table *I*, $V(\hat{\bar{W}}_t)$ are estimated and given in Table 1. Corresponding estimates for $V(\hat{G}_t)$ are obtained and given in Table 2. The estimates of P_{2t}, P_{3t}, P_{4t} and P_{6t} are also given in Table 2. The closeness of these estimates is worth noting. Variance functions for P_{3t} and P_{4t} are also found out. In this connection it is a problem to estimate $\rho(\hat{\bar{W}}_t,\ \log_e \hat{\bar{W}}_t)$. To get an idea about the magnitude of $\rho(\hat{\bar{W}}_t,\ \log_e \hat{\bar{W}}_t)$ first of all $\rho(W_t,\ \log_e W_t)$ was calculated and found to be almost unity. Then taking moving average of two for W_t and log values for the average, correlation was found to be almost unity. Further, moving average of three, four and five were also tried and in all these, correlation came closely to unity. On the basis of this observation, for the present example, correlation is taken as unity and thus $V(\hat{P}_{3t})$ is estimated from (35) putting $\rho(\hat{\bar{W}}_t) = 1$; one more assumption is also made that $V(\Sigma\hat{P}_{3t}) = \Sigma\, V(\hat{P}_{3t})$ and $V(\Sigma\hat{P}_{4t}) = \Sigma V(\hat{P}_{4t})$.

Variance estimates for ΣP_{3t} and ΣP_{4t} are alone found and given in Table 2 for comparison. Calculation of other variance estimates need not be difficult though they may take considerably more time. Proper computor programming will solve this problem. This would be considered subsequently.

Among the four production functions estimated, the estimates of P_3 alone does not fall within the confidence interval of either P_2 or P_4 though monthly estimates of these production functions do not vary much from each other as noted earlier. When P_4 is compared with P_2 of Ricker (1946) and Allen (1950) and P_6 of Gulin and Rudenko (op. cit) it is clear that to estimate P_4 as well as its variance function is much easier and less time consuming. The estimates of P_4 fares well with P_2 and P_6. Hence P_4 is preferable to other production functions considered here.

TABLE 1. *Generated monthly weight figures (g) with mean, variance and population number*

Generated values		Months May	June	July	August	September	October	November
1	..	1.2	2.3	2.1	3.7	4.6	6.5	6.7
2	..	2.0	2.4	2.9	3.6	4.4	6.7	6.9
3	..	1.2	1.9	2.4	3.3	4.7	6.7	6.8
4	..	1.3	1.8	2.6	3.2	4.0	6.6	6.7
5	..	1.6	1.9	2.8	3.6	4.4	6.6	7.2
6	..	1.3	1.8	2.3	3.0	4.5	6.3	7.2
7	..	1.9	1.8	2.8	3.6	4.6	6.5	6.6
8	..	1.7	2.0	2.0	3.8	4.7	6.1	6.6
9	..	1.4	2.0	2.8	3.6	4.6	6.3	7.2
10	..	1.6	2.0	2.8	3.1	4.4	6.6	7.0
11	..	1.2	2.3	2.3	3.7	4.7	6.2	7.3
12	..	1.3	1.9	2.7	3.4	4.9	6.6	6.4
13	..	1.3	2.3	2.6	3.7	4.1	6.5	6.8
14	..	1.6	1.9	2.2	3.9	4.0	6.4	6.5
15	..	1.4	2.3	2.5	3.8	4.1	6.8	6.6
16	..	1.8	1.7	2.6	3.6	4.4	6.3	7.3
17	..	1.6	1.7	2.4	3.1	4.5	6.6	7.1
18	..	2.0	2.3	2.3	3.5	4.8	6.5	7.2
19	..	1.2	1.9	2.3	3.7	4.7	7.0	7.0
20	..	1.4	1.8	2.6	3.1	4.9	6.2	6.9
$\hat{\bar{W}}$	..	1.5	2.0	2.5	3.5	4.5	6.5	6.9
$V(\hat{\bar{W}})$	..	0.0034	0.0025	0.0032	0.0036	0.0036	0.0024	0.0038
N	..	8,000	4,500	3,500	3,000	2,500	2,000	1,900

TABLE 2. *Estimates of G, Z etc.*

Period		Estimates $\hat{G}$	$\hat{Z}$	$\hat{\bar{B}}$ (kg)	$\hat{b}_{3t}$ (g)	$\hat{P}_{3t}$ (kg)	$\hat{P}_{5t}$ (kg)	$\hat{P}_{4t}$ (kg)	$\hat{P}_{6t}$ (kg)	$V(\hat{G}_i)$
May-June	..	0.29	0.58	10.5	0.5	3.0	3.1	3.1	3.0	0.00213
June-July	..	0.22	0.25	8.8	0.5	1.9	1.9	2.0	2.0	0.00113
July-August	..	0.34	0.15	9.6	1.0	3.3	3.2	3.2	3.3	0.00080
Aug.-Sept.	..	0.26	0.18	10.6	1.0	2.8	2.6	2.8	2.7	0.00047
Sept.-Oct.	..	0.37	0.22	12.1	2.0	4.5	4.5	4.5	4.5	0.00024
Oct.-Nov.	..	0.06	0.05	13.0	0.4	0.8	0.7	0.8	0.8	0.00007
				Total	..	16.3	16.0	16.4	16.3	
				$V(\hat{P})$	..	0.4573	—	0.5019	—	

APPENDIX

Let us assume $E(\hat{N}_t)=N_t$; $E(\hat{\bar{W}}_t)=\bar{W}_t$; $E(\hat{G}_t)=G_t$; $\rho(\hat{N}_t)=\rho(\hat{N}_{t+1})$ and $\rho(\hat{\bar{W}}_t)$ $=\rho(\hat{\bar{W}}_{t+1})$.

$$E(\hat{B}_t\hat{G}_t)=E[\hat{N}_t\hat{\bar{W}}_t\ (\log_e\hat{\bar{W}}_{t+1}-\log_e\hat{\bar{W}}_t)]$$

$$=N_t\bar{W}_t E(\log_e\hat{\bar{W}}_{t+1})-N_t E(\hat{\bar{W}}_t\log_e\hat{\bar{W}}_t)$$

$$=N_t\bar{W}_t E(\log_e\hat{\bar{W}}_{t+1})-N_t[\mathrm{Cov}(\hat{\bar{W}}_t;\ \log_e\hat{\bar{W}}_t)+\bar{W}_t E(\log_e\hat{\bar{W}}_t)]$$

$$=N_t\bar{W}_t G_t-\rho(\hat{\bar{W}}_t)N_t V(\hat{\bar{W}}_t)\ /\bar{W}_t$$

$$=B_t[G_t-\rho(\hat{\bar{W}}_t)V(\hat{\bar{W}}_t)\ /\bar{W}_t^2] \qquad \text{(A 1)}$$

Similarly

$$E(\hat{B}_{t+1}\hat{G}_t)=B_{t+1}[G_t+\rho(\hat{\bar{W}}_t)V(\hat{\bar{W}}_{t+1})\ /\bar{W}_{t+1}^2] \qquad \text{(A 2)}$$

Hence

$$\mathrm{Cov}(\hat{B}_t,\hat{G}_t)=-B_t\rho(\hat{\bar{W}}_t)V(\hat{\bar{W}}_t)\ /\bar{W}_t^2 \qquad \text{(A 3)}$$

and

$$2\,\mathrm{Cov}(\hat{\bar{B}}_t,\hat{G}_t)=\rho(\hat{\bar{W}}_t)\left[B_{t+1}\frac{V(\hat{\bar{W}}_{t+1})}{\bar{W}_{t+1}^2}-B_t\frac{V(\hat{\bar{W}}_t)}{\bar{W}_t^2}\right] \qquad \text{(A 4)}$$

Similarly

$$2\,\mathrm{Cov}(\hat{\bar{B}}_t,\hat{Z}_t)=\rho(\hat{N}_t)\left[B_t\frac{V(\hat{N}_t)}{N_t^2}-B_{t+1}\frac{V(\hat{N}_{t+1})}{N_{t+1}^2}\right] \qquad \text{(A 5)}$$

Now assuming $\rho[\bar{W}_t,(\log_e\hat{\bar{W}}_t)^2]=\rho(\hat{\bar{W}}_t)$

$$E[\hat{\bar{W}}_t(\log_e\hat{\bar{W}}_t)^2]=\mathrm{Cov}[\hat{\bar{W}}_t,(\log_e\hat{\bar{W}}_t)^2]+\bar{W}_t E(\log_e\hat{\bar{W}}_t)^2$$

$$\mathrm{Cov}[\hat{\bar{W}}_t,(\log_e\hat{\bar{W}}_t)^2]=\rho(\hat{\bar{W}}_t)\sqrt{V(\hat{\bar{W}}_t)V[(\log_e\bar{W}_t)^2]}$$

$$=2\rho(\hat{\bar{W}}_t)E(\log_e\hat{\bar{W}}_t)V(\hat{\bar{W}}_t)/\bar{W}_t$$

where $V[(\log_e \hat{\overline{W}}_t)^2] = 4[E(\log_e \hat{\overline{W}}_t)^2]\, V(\hat{\overline{W}}_t)\ /\overline{W}_t^2$

Hence

$$E(\hat{B}_t\, \hat{G}_t^2) = B_t\, E(\log_e \hat{\overline{W}}_{t+1})^2 + N_t\, E[\hat{\overline{W}}_t\, (\log_e \hat{\overline{W}}_t)^2] - 2N_t\, E(\log_e \hat{\overline{W}}_{t+1}) \times E(\hat{\overline{W}}_t \log_e \hat{\overline{W}}_t)$$

$$= B_t\, [V(\log_e \hat{\overline{W}}_{t+1}) + \{E(\log_e \overline{W}_{t+1})\}^2] +$$

$$N_t\, [\mathrm{Cov}\, \{\hat{\overline{W}}_t, (\log_e \hat{\overline{W}}_t)^2\} + \overline{W}_t\, E(\log_e \hat{\overline{W}}_t)^2] -$$

$$2N_t\, E(\log_e \hat{\overline{W}}_{t+1})\, [\mathrm{Cov}\, (\hat{\overline{W}}_t, \log_e \hat{\overline{W}}_t) + \overline{W}_t\, E(\log_e \hat{\overline{W}}_t)]$$

$$= B_t \left[G_t^2 + \frac{V(\hat{\overline{W}}_t)}{\overline{W}_t^2} - \frac{V(\hat{\overline{W}}_{t+1})}{\overline{W}_{t+1}^2} - 2\,\rho\,(\hat{\overline{W}}_t)\, G_t\, V(\hat{\overline{W}}_t)\ /\overline{W}_t^2 \right] \tag{A 6}$$

Similarly

$$E(\hat{B}_{t+1}\, \hat{G}_t^2) = B_{t+1} \left[G_t^2 + \frac{V(\hat{\overline{W}}_t)}{\overline{W}_t^2} + \frac{V(\hat{\overline{W}}_{t+1})}{\overline{W}^2_{t+1}} + 2\,\rho\,(\hat{\overline{W}}_t)\, G_t\, V(\hat{\overline{W}}_{t+1})\ /\overline{W}_{t+1} \right] \tag{A 7}$$

$$E(\hat{B}_t\, \hat{G}_t\, \hat{Z}_t) = B_t \left[\rho\,(\hat{N}_t)\, \frac{V(\hat{N}_t)}{N_t^2}\, G_t - \rho\,(\hat{N}_t)\, \rho\,(\hat{\overline{W}}_t)\, \frac{V(\hat{N}_t)}{N_t^2}\, \frac{V(\hat{\overline{W}}_t)}{\overline{W}_t^2} - \rho\,(\hat{\overline{W}}_t)\, \frac{V(\hat{\overline{W}}_t)}{\overline{W}_t^2}\, Z_t + Z_t\, G_t \right] \tag{A 8}$$

and

$$E(\hat{B}_{t+1}\, \hat{G}_t\, \hat{Z}_t) = B_{t+1} \left[\rho\,(\hat{\overline{W}}_t)\ \frac{V(\hat{\overline{W}}_{t+1})}{\overline{W}_{t+1}^2}\, Z_t - \rho\,(\hat{N}_t)\, \rho\,(\hat{\overline{W}}_t)\, \frac{V(\hat{N}_{t+1})}{N_{t+1}^2}\, \frac{V(\hat{\overline{W}}_{t+1})}{\overline{W}_{t+1}^2} - \rho\,(\hat{N}_t)\, \frac{V(\hat{N}_{t+1})}{N_{t+1}^2}\, G_t + Z_t\, G_t \right] \tag{A 9}$$

Now

$$E(\hat{B}_t^2\, \hat{Z}_t) = E(\hat{\overline{W}}_t^2)\, E(\hat{N}_t^2 \log_e \hat{N}_t) - E(\hat{\overline{W}}_t)^2\, E(\hat{N}_t^2)\, E(\log_e \hat{N}_{t+1})$$

$$= [V(\hat{\overline{W}}_t) + \overline{W}_t^2]\, \{[2\,\rho\,(\hat{N}_t)\, V(\hat{N}_t) + E(\hat{N}_t^2)\, E(\log_e \hat{N}_t)] - [V(N_t) + N_t^2]\, \log_e (\hat{N}_{t+1})\}$$

$$= [V(\hat{\overline{W}}_t) + \overline{W}_t^2]\, [2\,\rho\,(\hat{N}_t)\, V(\hat{N}_t) + \{V(\hat{N}_t) + N_t^2\}\, Z_t] \tag{A 10}$$

Similarly, assuming that

$$\rho\,(\hat{N}_t, \log_e \hat{N}_t) = \rho\,(\hat{N}_t^2, \log_e \hat{N}_t)$$

$$E\,(\hat{B}_{t+1}^2\, \hat{Z}_t) = [\, V\,(\hat{\overline{W}}_{t+1}) + \overline{W}_{t+1}^2\,]\,[\,\{\, V\,(\hat{N}_{t+1}) + N_{t+1}^2\,\}\; Z_t - 2\,\rho\,(\hat{N}_t)\; V\,(\hat{N}_{t+1})\,] \qquad \text{(A 11)}$$

Now

$$E\,[\,(\hat{\overline{W}}_{t+1} - \hat{\overline{W}}_t)\;(\hat{N}_t - \hat{N}_{t+1})\;\hat{Z}_t\,] = (\overline{W}_{t+1} - \overline{W}_t)\; E\,[\,(\hat{N}_t - \hat{N}_{t+1})\;\hat{Z}_t\,]$$

$$= (\overline{W}_{t+1} - \overline{W}_t)\;[\,E\,(\hat{N}_t \log_e \hat{N}_t) - N_t\,(E \log_e \hat{N}_{t+1}) - N_{t+1}\, E\,(\log_e \hat{N}_t)$$

$$+ E\,(\hat{N}_{t+1} \log_e \hat{N}_{t+1})\,]$$

$$= (\overline{W}_{t+1} - \overline{W}_t)\;\left[\,\rho\,(\hat{N}_t)\left\{\frac{V\,(\hat{N}_t)}{N_t} + \frac{V\,(\hat{N}_{t+1})}{N_{t+1}}\right\} + Z_t\,(N_t - N_{t+1})\,\right] \qquad \text{(A 12)}$$

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STATISTICAL DESIGNING OF AQUACULTURE EXPERIMENTS

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Abstract

Experiment is the main tool of a researcher. The effect of factors or treatments can be assessed only by testing them experimentally. Several factors like composition of stock, density of stock, feeding level, depth of water and salinity come into play in aquaculture experiments. Sometimes the problem may be one of developing a low-cost technology which can be gainfully employed by small and marginal farmers. Here again a number of factors under study act and interact. The main difficulty in such situations is that effects of extraneous factors very often mask the real treatment effect. One way to overcome this difficulty is to use homogeneous experimental material. However there are very many practical limitations to achieve such an end. A statiscally planned experiment attempts to minimise effects of heterogeneity in experimental units from treatment comparison, reduce experimental error, provide unbiased estimates and ensure validity of test of significance. The paper discusses at length the various statistical requirements in experimentation with special reference to coastal aquaculture systems.

Introduction

For food or for fun, fish farming has been in practice since ancient times. In the course of centuries the area of farming expanded and technological innovations found their place. From earlier pond system culturing have grown to include flowing water and enclosure systems not only in the inland waters but also in estuaries, backwaters and open sea. Today, in several countries of the world, scientifically managed fish farming has become an accepted method for augmenting fish production (Brown, 1977).

Compared to the inland waters, marine environment is often aggressive and the task of evolving mariculture methods suiting different ecosystems is quite formidable and a good deal of research in this direction is in progress (Bardch *et al.*, 1971). In India too, scientists are deeply involved in research to improve the traditional methods of coastal aquaculture and to develop production technologies which are feasible and economically viable.

The main tool of a research worker is experiment. The effect of factors or treatments can be assessed only by testing them experimentally. Several aspects like depth of water, salinity, composition of stock, density of stock and feeding levels come into play in aquaculture experiments. As many factors act and interact a difficulty faced is that effects of factors extraneous to those under study mask the treatment comparisons under test. A statistically planned experiment attempts to reduce the effects of extraneous factors from treatment comparisons and has many desirable properties. The paper explains the need for statistical designing and discusses various situations in coastal aquaculture experimentation where statistical designs can be gainfully employed.

Need for Statistical Designing

It may look strange that while statisticians themselves do not generally conduct experiments they express their claim to have a say at the stage of planning as well as at later stages. It is the scientific nature of an experiment which compels the need for meeting statistical requirements (Kempthorne, 1972). Statistical designing of an experiment involves the formulation of a scheme or a lay out plan, where the placements of treatments in experimental units are specified to suit the requirements of the particular problem keeping in view the requisite statistical principles. The term 'treatments' is used here in a general way and may mean species, levels of feeding, doses of stimulant, stocking densities, etc.

Variability in experimental material is an inevitable freature in any field of research. Consider for example two prawn culture ponds kept under conditions as similar as possible with the same extent of area, species, stocking density, etc. At the time of harvesting one would find that the yield of one pond is different from the other. This may be attributed to the uncontrolled variation inherent in the production process. Consider another two ponds again kept under almost identical conditions except that in one pond supplementary feeding is given. Here again, at the time of harvesting the yields would be found to be different. Can we attribute the difference straightaway to the effect of levels of feeding? We cannot. May be the supplementary feeding did not contribute anything to the difference in yield and the difference could be purely due to the inherent uncontrolled variation. Differences are expected even when similarity is maintained in the two ponds. One might then say that if the difference is quite high it can be attributed to the difference in the level of feeding. But how high the difference should be to attribute it to the level of feeding? The answer becomes quite subjective. Thus variation introduces a degree of uncertainty into the conclusions that are drawn from the results. A mathematical measure of uncertainty is probability, the theory of which enables us to make numerical statements about uncertain outcomes. But unless the planning is made taking into consideration statistical principles it would not be apt to make such statements regarding the outcome.

The formulation and testing of hypothesis are the main features of a scientific method (Kempthorne, 1972). A researcher postulates a hypothesis which he would like to verify. This verification necessitates the collection of observations through an experiment and the designing of experiment is concerned with the pattern of observations to be collected which should be relevant to his hypothesis. It may be stressed here that when we draw inductive inferences from experimental data, every statement of results is subject to some error, an error about which probability statements may be made with the aid of mathematical statistics. Only a statistically designed experiment can permit a valid test of significance involving probability statements whether a particular difference is due to chance causes or can be attributed to the real differences between two treatments.

As indicated earlier the results of an experiment are affected not only by the action of treatments, but also extraneous variation which tend to mask the effects of treatments. This extraneous variation is conventionally termed as 'experimental error' (or sometimes called 'error') where the word 'error' is not synonymous with mistakes, but indicates all types of extraneous variation (Cochran and Cox, 1973). There are two sources of experimental error, one refers to the inherent variability in the experimental material or units to which the treatments are applied and the other type refers to the failure to standardise the experimental technique. It is desirable that the experimental error is kept as minimum as possible as otherwise only a large difference in the treatment means will be detected as significant. Reduction of experimental error automatically increases the precision. One way to reduce the error is by ensuring uniformity in the conduct of the experiment. Two other methods to increase the precision of the estimates are one by providing more replications and the other by skillful grouping of units in such a way that the units to which one treatment is applied are closely comparable with those to which another treatment is applied. Some of the general principles governing these methods and other related aspects are elaborated.

Two primary requisites in designing experiments are replication and randomisation. Replication or repetition of treatments provides stability to the mean, but more than that makes it possible to estimate the experimental error. It also increases the precision of the estimates of both the treatment mean and the experimental error.

Randomisation which means random allocation of treatments to various experimental units, ensures that a treatment will not be unduly favoured or handicapped in successive replications. It ensures unbiasedness of the estimates of experimental error and provide for valid treatment comparisons against the experimental error (Fisher, 1949). When treatments are replicated and allocated randomly to the various units we are in a position to test the significance of observed treatment differences by the use of test of significance procedures. Thus it is essential to provide for adequate number of replications and ensure proper randomisation at the planning stage (Panse and Sukhatme, 1964).

Grouping of units often help in reducing the experimental error. Consider for instance an experiment with a number of replications, all the treatments being tried in each replicate. The error from any replicate can arise from sources of variation that affects the units within the replicate. Variation between replicates do not contribute to the error. Thus if the experimental units form a very heterogeneous set, try to group them so that units in the same replicate is as homogeneous as possible while variation between replicates could be large. By this process, from the total variation in the observations the variation between replicates can be removed resulting in the reduction in the error variance (experimental error). The device of reducing errors through suitable groupings is called local control. Looking from another angle, if treatments are allotted to a replication with homogeneous units the observed differences would reflect the real differences between the treatment effects. The principle of local control is the basis for experimental designs such as 'randomised blocks' and 'latin squares'. When the number of treatments to be accommodated in a replicate becomes large, the homogeneity within a replicate tends to be lost and can be restored by dividing the replication into smaller blocks which is the basis of 'confounding' in factorial experiments and also various 'incomplete block designs'.

To sum up, statistical designing of experiments attempts to minimise the effects of heterogenity in experimental units from treatment comparisons, reduce experimental error, provide unbiased estimates and ensure validity of test procedures. The test of significance emanating from the design exerts a sobering influence on the type of experimenter who jumps to exciting conclusions that can as well be ascribed to the natural variation inherent in the experiment (Cochran and Cox, 1973).

Some Useful Designs

(i) Randomised block

One of the most commonly used plans is the randomised block design where experimental material is divided into blocks each of which constitute a single replicate in such a way that the units within a block is as homogeneous as possible. The treatments are now randomly allotted to the experimental units within a block. This increases the comparability of treatment effects as they act under conditions which are similar except for the treatments. For instance in an experiment to select an economic supplementary feed mixture from among 4 prepared mixtures for prawn culture, 4 ponds all located by the side of the main water body like the backwater or estuary could be grouped as one block or replication and allot treatments at random. The next 4 could be ponds running parallel to the first set, but more inside the land so that within a block salinity and associated features are likely to be similar. This arrangement takes care to a good extent salinity gradient likely to be reducing when moved away from the main water body. In the experiment if there are 5 replications there will be total 20 ponds. If all the 20 ponds are more or less similar no blocking or stratification is required and the treatments could be randomly allotted over the entire range of the 20 ponds. Such a design is called completely randomised design. However if heterogeneity in the features of the ponds is suspected it is desirable to provide blocks which may help in reducing the experimental error.

(ii) Latin square

In randomised blocks one-way restriction is imposed. If heterogeneity is suspected in two directions the experimental area can be divided into, say, rows and columns and treatments are applied in such a way that each treatment appears only once in a row and once in a column. Such an arrangement is called a latin square design. Through elimination of row and column effects the residual error variance may be very much reduced. Consider the question of finding out the best spat attachment material from among say, 4 materials like tile, brick, concrete and asbestos pieces. A raft with 4 poles in rows and 4 in columns can be fabricated and at the 16 junctions hang ropes on which the material is tied. The placement of the 4 materials can be fixed following a 4×4 latin square arrangement. Effects of two-way variation like current direction or nearness to the exterior portion of the floating raft could be reduced from comparison between the quantity of spat collected on the different materials. If three-way and higher-way grouping of treatments is required designs like graeco-latin squares and hyper graeco-latin squares can be attempted (Federer, 1967). The procedure of using latin and graeco-latin cubes also could be explored. With two-way stratification the latin square controls more variation than randomised block design resulting often in a smaller error mean square. However the number of treatments is limited to the number of rows or columns and for large number of treatments latin square design is not preferred.

(iii) Factorial experiments in complete and incomplete blocks

Consider an experiment to study the effect of different levels of protein and energy on weight of fish in culture ponds. If there are say, 2 levels for each factor there will be in all 4 (2^2) treatment combinations. A group of treatments which contains two or more levels of two or more factors in all combination is known as the factorial arrangement. The different combinations could be allotted as in a randomised block design. The experimenter could try a one-factor-at-a-time approach. But the advantage in a factorial experiment is that not only the main effects, but also the interactions between factors can be studied and tested for statistical significance.

If the number of factors and levels are large say 3 factors, salinity, temperature and oxygen content at 3 levels each, the number of treatment combinations will be 27. It may be difficult to get 27 experimental ponds, which are more or less homogeneous with regard to factors other than being tested so that the principle of stratification to reduce experimental error cannot be implemented. An ingenious device to overcome this situation is called confounding where a homogeneous block will not accommodate the full replication. One replication is divided into say, 3 compact blocks such that the units in the smaller blocks are homogeneous. The 27 treatment combinations can be divided into 3 groups of 9 each and allotted to the 3 compact blocks. However some of the treatment comparisons will not be distinguishable from block differences or in other words, get confounded with block differences. Thus some sacrifices have to be made. But at the planning stage this aspect can be considered and the scheme can be so formed that all major and important comparisons are kept free from block differences. Factorial set-up can be easily superimposed in polyculture experiments in pens or in ponds.

(*iv*) *Split-plot*

In the usual factorial trial, the effects are estimated with the same degree of precision. It is quite possible that some factors may produce much larger differences than others and in the factorial set-up the precision attained could be sufficient to bring out the significance of the differences between levels of factors capable of showing large difference, but may not permit detection of smaller difference, between the levels of the other factor, (Panse and Sukhatme, 1964). A device known as 'split plot' where the levels of the 2nd factor which we wish to compare with greater precision are assigned to contiguous plots under a common level of the first factor. This effects greater local control. Thus each block is divided into main plots where the level of the first factor is allotted at random and next subdivide each main-plot to subplots to which are allotted at random the levels of the second factor. For instance if 3 species of fish are to be compared in an experiment in pens fabricated in the inshore water for growth with 2 types of supplementary feeding, instead of putting all the 6 combinations at random in a block of 6 pens, arrange the three species of fish to three pens and next subdivide each pen into two sub-pens to be randomly allotted to the two feeds. Enough replications will have to be provided.

(*v*) *General incomplete block*

There are situations where a large number of treatments which are not of factorial type are to be tried. Then the factorial type arrangement with or without confounding may not be suitable and one has to look for other procedures for reducing the block size. The general incomplete block designs come handy in such cases. Here the number of units in a block will be less than the number of treatments. When homogeneous number of units in a block is quite small these design are useful. For instance in induced breeding of say, *Sillago sihama* by injecting pituitory harmones one may like to study the effect of the level of the dose injected. Similar type of fish suited for the study may be available at a time only in small numbers say 3 and if 5 doses are to be tried we can have a plan where number of units in a block of homogeneous units is 3. The pattern of allotment of the 5 doses in the blocks of 3 homogeneous units each can be taken from the catalogue of plans available (Cochran and Cox, 1973). The method of analysis of the data collected will be complex compared to some of the designs mentioned earlier.

(*vi*) *Switch-over*

There are occasions in which treatments are applied in sequence over several periods on a group of individuals. Consider an experiment to study the effect of mineral supplementation of two types in lobsters kept in artificial tanks. If there are say six groups of lobsters separated and kept in tanks with sub-partitioning then the two types of supplementation, are given such that half the groups received say, type A and the other half type B in period 1. The lobsters receiving type A in period 1 will be switched over to get type B in period 2 and vice versa. Such a design is called switch-over or change-over design (Federer, 1967). On the other hand if a time trend is expected in the character under study a switch-back or a double reversal design will have to be used. In these procedures a rest period is to be provided between two treatment periods so that there is no carry-over effect or residual effect influencing the treatment during the second period. However if a reasonably long rest period is not feasible or the residual effect is itself a topic of interest the procedure is to be modified so that direct and residual effects of treatments can also be measured.

(vii) Rotatable

In factorial experiments with quantitative variables like temperature, salinity, amount of oxygen and level of nutrients the yield or response say y, can be considered as a function of these variables. If we assume a linear multiple regression of y on the variables, $x_1, x_2, \ldots x_k$ the levels of which are controlled by the experimenter then the relationship comes under the model

$$y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \ldots \beta_k x_k + \epsilon$$

Where β's are the regression coefficients and ϵ random component. From observed data it would be possible to estimate the coefficients by least square procedure and then the function gives a complete summary of the results of the experiment. A design which is specially oriented to study, such response functions is called rotatable design which has some additional desirable properties compared to the usual designs. The lay-out plans for such designs are available in many publications (Cochran and Cox, 1973). A second order rotatable design which is not very complex can be used for the determination of the levels of factors like amount of oxygen and salinity needed for optimum production.

Statistical Analysis

Once a design is fixed the procedure of analysis follows. We can postulate a mathematical model to represent a design. As an example the linear additive model underlying the randomised block design can be written as

$$y_{ij} = \mu + \tau_i + \rho_{ij} + \epsilon_{ij}$$

where μ represents the general mean, τ the effect of treatment, ρ the effect of block and ϵ the random component. Under a set of assumptions it is possible to estimate the treatment and block effects. The components of variation due to treatments, blocks and error can be computed and the analysis of variance Table can be prepared which facilitates test of significance of treatment differences and drawing conclusions so that appropriate decisions can be taken. Similar procedures are available for other designs as well.

Some experimenters do not bother to follow a design, but try to analysis the data statistically. Some others follow a design, but do not care to follow the appropriate procedure of analysis. It is essential in scientific experimentation to follow a suitable design and analyse the data through appropriate statistical procedures.

Much has been talked about the problem of getting homogeneous experimental units for allotment of treatments by using local control methods to reduce the experimental error. In addition there is a purely statistical procedure to reduce the error variance called 'analysis of covariance' where information on a suitably chosen auxiliary variable is used to adjust the error sum of squares by subtracting from it the sum of squares due to the regression of say yield, on the auxiliary variable (Snedecor and Cochran, 1967). The technique provides a powerful method of reducing error variance and should be availed of by the experimenter wherever possible.

Discussion

With increase in the volume of research in mariculture involving prawns, lobsters, crabs, mussels, oysters, clams, finfishes and seaweeds there is an excellent scope for the employment of statistical designs. It is an accepted fact that mariculture problems have to be dealt with a multidiciplinary approach and statisticians working in fisheries research have an important responsibility. It is imperative that any scientific experiment need to be statistically planned so that the emanating data become amenable to statistical analysis for arriving at valid conclusions needed for decision-making.

One aspect need to be stressed here, namely, the provision of enough number of replications in an experiment. Consider the example of 4 feed mixtures which are tried for economic evaluation in prawn culture. If the mixtures are allotted only one each in four ponds without replications we will get only a single figure on, say, cost of production of a unit weight, for one mixture. Thus with four treatments the character under study will have only four figures, a single figure for each, and no statistical analysis is possible. One way is to partition the ponds into 4 sub-ponds which may provide 16 figures 4 each for one treatment for analysis. It my be stressed that apart from reducing experimental error replication of treatments alone can provide an estimate of the experimental error essentially needed for treatment comparisons.

The question of minimum number of replications required is of great importance in coastal aquaculture experiments because of the cost involved and the inherent special problems, compared to experiments on land. An important consideration in determining the minimum number of replications is that the test of significance should be sufficiently sensitive to detect real difference between treatments as distinguished from variation due to chance causes. The sensitiveness of the test will depend primarily on the magnitude of variation in the experimental units with regard to the character under study. If the magnitude is known the number of replications required for detecting a particular difference with a certain level of confidence can be worked out (Federer, 1967; Panse and Sukhatme, 1964). In the absence of any knowledge regarding the magnitude of variability the number of replications provided should be at least sufficient to ensure 12 degrees of freedom for error. This is inferred from the fact that the tabulated value of 'F' at the conventional level of significance of 5 per cent ceases to fall off rapidly for degrees of freedom beyond 12. On this basis the minimum number of replications can be worked out for a particular design (Jacob and Marutiram, 1975).

In the preceeding paragraphs some guidelines in planning experiments have been dealt with. Some of the standard designs available in literature which can be used with advantage in coastal aquaculture experiments have been enumerated. It may however be observed that considering the experimental resources available and the special nature of problems some amount of 'tailoring' may have to be resorted to for suiting particular situations.

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HISTORY OF CULTURING THE AMERICAN LOBSTER *HOMARUS AMERICANUS* IN THE UNITED STATES

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ABSTRACT

Following the development of the lobster fishery in New England about 1800, it become apparent the culturing lobster fry was desirable to supplement natural reproduction. Experimental lobster culture began at Woods Hole, Massachusetts, in 1885. The McDonald automatic hatching jar was most successful in hatching, but because of cannibalism fry were liberated at once. Attempts at feeding fry were not successful. In 1887 a hatchery was opened at Cold Spring Harbour (N.Y.), and in 1894 another one at Gloucester, Mass. During 1898-99 H. C. Bumpus experimented with rearing fry at Woods Hole, followed by A. D. Mead at Wickford, R. I., who developed a floating laboratory. V. E. Emmel experimented with feeding and E. W. Barnes improved the apparatus. In 1905 a hatchery was started at Boothbay Harbour, Me. and in 1906 another one at Noank, Conn., but they did not prove to be effective. In 1947 an experimental laboratory was established at Martha's Vineyard, Mass., under J. T. Hughes for research on lobster biology and propagation. In recent years experimental studies on culturing the American lobster have been pursued by R. A. Shleser, D. E. Conklin, A. N. Sastry and their co-workers. Practical methods are still needed.

HISTORY

THE AMERICAN lobster fishery, as a commercial venture, began on the coast of Massachusetts about 1800, and on the Maine Coast about 1840. Before the end of the 19th century it was realized that some kind of management was needed to maintain the fishery at a commercial level. In addition to legal controls it was long believed that artificial propagation would be effective. The Norwegians had carried out early experimental work in hatching and rearing fry of the European lobster (Anon., 1876).

In 1872 the Commonwealth of Massachusetts retained 'berried' lobsters in a 'lobster park' to permit the eggs to hatch. About 1875 a similar one was established on the coast of Maine, but it was soon realized that simply holding females with eggs until they hatched was ineffective. With the new marine laboratory and hatchery opened at Woods Hole, Mass., in 1885 by the U. S. Fish Commission, experimental work on lobster culture began in this country. Newly hatched fry were liberated in Vineyard Sound and adjacent waters. The Chester jar, the McDonald tidal box and the McDonald automatic hatching jar were used, of which the last was most successful. Upto 1889 average production of fry was 54%. Between 1890 and 94 production reached 81% and in 1894 it was increased to 90-93%. Millions of fry were obtained, but because of intense cannibalism, the fry were liberated at once. (Smith, 1898; Anon., 1900). Experiments on rearing were carried out under the direction of Capt. H. C. Chester, using hatchery jars and feeding the fry on minced crab or lobster meat (Ryder, 1886). During 1884-85 Richard Rathbun joined Capt. Chester in experimental work with McDonald jars. The following year Prof. J. A. Ryder joined the project and attempted to raise the larvae by feeding them on copepods and other plankton organisms, crab roe and chopped meat. The work was still experimental and not yet practical, primarily because of cannibalism (Rathbun, 1887 ; 1892).

In 1887 a lobster hatchery was opened at Cold Spring Harbour by the New York State Commission of Fisheries and operated for a number of years. Berried lobsters were obtained from Connecticut (Mather, 1895). In 1894 the U. S. Fish Commission established a second lobster hatchery at Gloucester, Mass., in addition to the original one at Woods hole.

Capt. A. C. Adams, formerly master of the schooner *Grampus* which brought egg-lobsters to the hatcheries, became the fish-culturist at the Gloucester Hatchery in 1893, and introduced the hatching of lobsters such as was done at Woods Hole (Bean, 1896 ; Dexter, 1979 a).

In 'The Fishery Industries of the United States' G. Brown Goode (1884-87) wrote, 'The artificial propagation of lobsters has been rarely attempted, either in this country or in Europe and in no case are we aware of its having been productive of satisfactory practical results. There are so many difficulties to overcome in an undertaking of this character and the breeding habits of lobsters are so imperfectly understood, that it is not surprising that greater progress has not been made in materially aiding the increase in supplies by artificial culture, as in the case of the oyster and of many of our true fishes.' In 1893 Francis H. Herrick gave a report on the pioneering work done at Woods Hole to the World's Fisheries Congress held at Chicago as part of the World's Columbian Exposition. He suggested that the lobster fry be retained until they reached the settling stage (4th stage) before being liberated (Herrick, 1894).

During 1898-99 H. C. Bumpus carried out experimental studies on rearing lobster fry at Woods Hole (Dexter, 1979). He had best success with bags of cotton scrim attached to a wooden frame floating on the surface. Movement of the scrim from wave and wind action kept the larvae suspended in the water. The next season he tried several localities to determine which would be best. His method was put into operation at Woods Hole and at Annisquam (On Cape Ann) Mass., Orr's Is., (on Casco Bay), in Maine, and at wickford R. I. At Woods Hole he tried to use only natural plankton for food, but it was found insufficient so that lobster liver was added. At Annisquam both clams and lobster liver were used for feeding, but a gale upset the float and the fry were lost. At Orr's Is. lobster liver was used as food, but in all cases mortality was high because of cannibalism. At Wickford Dr. A. D. Mead from Brown University, serving on the Rhode Island Commission of Inland Fisheries, cooperated in the project. He constructed a floating laboratory from which the frames with scrim bags were suspended and crews constantly stirred the water with an oar. Fry were obtained from the Woods Hole station and chopped clams and lobster liver were used as food. The fry were retained to the 4th stage before being liberated, at which time they seek the bottom. With better facilities and warmer water, Mead had better success than at other localities. The project was then concentrated at Wickford with the cooperation of the R.I. Commission of Inland Fisheries. In 1901 George H. Sherwood devised a 2-bladed propeller to keep the fry suspended, and thus dispensed with the hand-labour of stirring with an oar. The next season he built a similar floating laboratory at Woods Hole. He tried ground menhaden as food, which proved to be practical, but cannibalism and the growth of diatoms on the fry reduced productivity. It was concluded that everything considered, Woods Hole was not as good a locality as Wickford (Sherwood, 1905).

Prof. Frederick P. Gorham at Brown University assisted with the work at Woods Hole and from his experience recommended that the water be filtered to control diatoms, relocate where diatoms are not so abundant, change the scrim bags frequently, reduce light intensity and raise the fry as rapidly as possible in warm water (Gorham, 1905).

Efforts had been made at Wickford since 1898 without success until Bumpus, a commissioner for R. I. Fisheries, began his work at Woods Hole and brought his method to Wickford. In 1900 A.D. Mead continued the work as mentioned above, and issued an annual report of progress (Mead, 1901, 1902; Mead and Williams, 1903, 1904). V. E. Emmel (1908) experimented with different foods and concluded that ground beef was better than clam, lobster, or fish muscle, or beef liver, for feeding lobster fry. Mead (1910) continued the search and found scrambled eggs (uncooked) to be successful. Broken eggs and unmarketable eggs could be purchased cheaply. E. W. Barnes (1911) became superintendent of the Wickford Experiment Station and made many changes and improvements in both the method and the apparatus. Wooden boxes replaced canvas bags, and a unit system for raft structures was introduced. Hen's eggs were used for food, but they were fried without grease and pulverized which seemed better than using raw eggs. Barnes recommended raising the fry the 5th or even 6th stage of development before they are liberated. Cannibalism, however, made delayed liberation inefficient, but Barnes did succeed in obtaining 40-48% 4th stage fry from newly hatched larvae. The New England hurricane of 1938 destroyed much of the R.I. plant and another strom of 1944 put a finish to the programme.

In 1904 the U.S. Commission of Fish and Fisheries leased a lobster pond at Boothbay Harbour, Maine, but since the hatchery was not yet ready, the berried lobsters were sent to Gloucester for hatching. The following year the hatchery was in operation, but fry were released soon after hatching in spite of experience elsewhere that immediate release was ineffective. Between 1919-1936 the Gloucester and Boothbay Harbour stations were closed. Following the Second World War they were in operation again for a decade, but then were closed permanently.

In 1906 the Connecticut State Board of Fisheries and Game installed a lobster hatchery at Noank. In 1929 a modern system was introduced (Cobb, 1932), based on wooden boxes originally devised by Earnest W. Barnes, but modified by Frank N. Banning and hence commonly known as the Banning Box. Ground beef liver was used for food. In the summers of 1945 and 1946, the writer was engaged to study the operation and to experiment with lobster rearing. Some improvements were suggested (Dexter, 1952, 1955), but it was generally recognized that hatcheries for the exclusive purpose of hatching and rearing lobster fry at that time were not very effective, if at all. The station was closed in the following year. At the same time the Commonwealth of Massachusetts established a station on Martha's Vineyard for research on basic biology and lobster problems of propagation and management under J. T. Hughes (Hughes *et al.*, 1974) who has developed a successful modern programme of lobster research. Bibliographies of lobster culture have been published by Scatlergood (1949) and Dawson (1954). Recent accomplishments in experimental lobster culture have been reported by Shleser (1974), Conklin (1975), Sastry (1975) and their co-workers. A good practical method of culturing the American lobster is still needed.

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GROWTH OF THE SPINY LOBSTER *PANULIRUS POLYPHAGUS* (HERBST) REARED IN THE LABORATORY

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ABSTRACT

Growth of *Panulirus polyphagus* from the puerulus stage was studied in the laboratory for twenty eight months on a diet of *Meretrix casta* and *Perna viridis*. The lobsters were kept either in isolation or in groups of three per tank at laboratory temperature ranging between 21.4° and 29.5°C. The survival was higher (70%) in those reared in groups, however, the growth rate was not depressed in individuals held in isolation.

Carapace length positively correlated with total weight in both sexes of the tested individuals. In captivity the male grew faster than the female. For male the increase in carapace length on an average was 3.3 mm for each moult while it was only 2.6 mm for the female. But there was slight difference in intermoult duration between the sexes. The annual growth rate was 34 mm in carapace length for male and 28 mm for female during the first year and 20 mm for male and 20.5 mm for female during the second year. The female attained maturity at an average carapace length of 48 mm. Temperature affected growth ; the intermoult duration was prolonged at low water temperature.

INTRODUCTION

PALINURID LOBSTERS which is a highly priced commodity, forms a meagre fishery in India (CMFRI, 1979). But the occurrence of puerulii has been reported periodically in both east and west coasts of India (Rao and Kathirvel, 1971 ; Girijavallabhan and Devarajan (1972) ; Dutt and Ravindranath, 1975). Tholasilingam (1976) reported abundance of three different species of puerulii off Kovalam. It is possible to culture lobsters from the puerulii available in nature to adult sizes. Chittleborough (1974) and Phillips *et al.* (1977) reared a group of *Panulirus longipes cygnus* from puerulus to adult under subtropical conditions. Fielder (1964) studied the moulting and growth in temperate lobster *Jasus lalandei.* In India, Deshmukh (1966) studied the early metamorphosis of *Panulirus polyphagus.* Thomas (1972) reported the growth of *Panulirus homarus* in captivity and Kathirvel (1973) observed regeneration of a lost antenna with depressed growth in *P. polyphagus.* However, little is known on the growth pattern of tropical palinurid lobsters. The growth of the commercially important palinurid lobster *P. polyphagus* from puerulus to adult stage is reported for the first time in India.

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MATERIAL AND METHODS

In early May 1977, fifteen puerulus larvae of the spiny lobster *Panulirus polyphagus* measuring an average of 8.5 mm in carapace length were collected off Kovalam from Mangalore tiles suspended from a floating raft. They were brought to the field laboratory at Kovalam and acclimatized in three plastic tanks with a floor area of 0.16 sq.m. Five puerulii were held in each tank and were fed *ad libitum* on flesh of freshly opened clams *Meretrix casta* collected daily from Kovalam backwaters and green mussel *Perna viridis*. The lobsters seem to prefer mussel to clams. During the first nine months only monthly increase in carapace length and weight of lobsters were recorded.

After nine months, nine healthy individuals were selected and divided into two series. The first series consisted of six animals divided into two groups of three juveniles each and the second series with three animals placed in individual aquarium. Each fibreglass aquarium holding the animals had a floor area of 50×45 cm with 250 litres of filtered sea water. The animals were provided with hollow tiles for shelter.

The water in the aquarium was replaced twice a week by fresh filtered sea water. Salinity of the water in the aquarium varied from 32.5‰ to 36.2‰ and that of temperature from 21.4°-29.5°C. The water was aerated continuously. The aquarium tanks received 16 hr illumination.

The juvenile lobsters were fed on *Meretrix casta*. Food was supplied daily at dusk and the uneaten food was removed on the following morning. Preliminary observations revealed that the animals did not feed during day time. The tanks were cleaned once a week with least disturbance to the lobsters.

Growth measurements of individual lobsters were taken five days after each moult when the exoskeleton had sufficiently hardened. The size was recorded by measuring the carapace length (CL) to 0.1 mm accuracy along the mid-dorsal line from the ridge behind the eyes (between the rostral horns) to the posterior margin of the carapace. This was used as the standard length (Berry, 1971) in the present study. Live bodyweight of the animals was measured after removing free water as described by Chittleborough (1975).

In crustaceans increase in length and weight occur at and just following moulting. So the two interacting components involved in the growth processes are (*a*) moult increment (increase in size per moult), (*b*) intermoult duration (duration of the intermoult period). Here growth is mainly referred to as increase in carapace length and weight and growth rate as growth with time.

RESULTS AND DISCUSSION

Growth of male and female P. polyphagus

When collected from the sea, the transparent puerulus larvae of *P. polyphagus* had a mean carapace length of 8.5 mm and weighed an average of 260 mg. The larvae did not feed till they completed the first moult. Within 2-4 days of their capture, about 80% of the larvae moulted to the post-larval phase.

As only the monthly averages of carapace length and weight were recorded during the first nine months of growth, the intermoult duration and moult increment for the period could not be studied. Fig. 1 presents the growth of male and female lobsters reared in groups for a period of 840 days from the time of capture. The males exhibited faster growth rate than the females resulting in larger size in unit time. The estimated average annual increment in carapace length was 34 mm in males and 28 mm in females during the first year and 20 mm and 20.5 mm in carapace length for males and females respectively in the second year. The differential growth between sexes has been reported by earlier workers for both wild and laboratory reared palinurid lobsters. Mohammed and George (1968) observed higher growth rate in males than in females of *P. homarus* from mark-recovery studies. Thomas (1972) also estimated an average annual increase in carapace length of 30 mm in males and 17 mm in females of *P. homarus*. But Chittleborough (1974) and Phillips *et al.* (1977) found no difference in the growth rate of males and females of *P. longipes cygnus*. It is interesting to note from Fig. 1 that the growth curve of the female

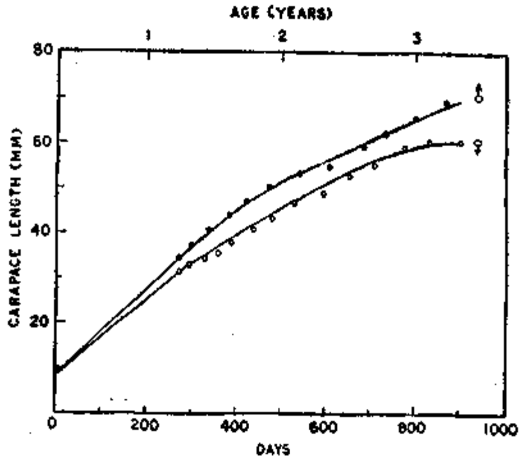

Fig. 1. *Panulirus polyphagus:* Mean increase in carapace length (mm) of males and females reared in groups during 840 days; each point represents the average of about 3 individuals.

tapers off at about 42 mm CL, whereas it is not the case with males. This is apparently due to deceleration of growth rate in females which becomes evident at the time of attainment of sexual maturity (Berry, 1971). The females of *P. polyphagus* attained sexual maturity at an average carapace length of 48 mm when the lobsters were 2.2 years old. Philipps *et al.* (1977) estimated the age of *P. longipes cygnus* as 2.3 years old when the lobsters reached 40-42 mm CL. The difference in age between *P. polyphagus* and *P. longipes cygnus* was not due to the faster growth rate of *P. polyphagus*, but the estimated difference in age of settling puerulus larvae. Chittleborough and Thomas (1969) reported the age of newly settled puerulus larvae of *P. longipes cygnus* as 0.8 years whereas the age of puerulus of *P. polyphagus* was estimated as 0.4 years using the same method. The CL of female *P. polyphagus* in the present study reach asymptotic level when it was three years old during which period the male was still in its upward growth phase (Fig. 1). The differential growth rate may have some far reaching implications as it has been shown that the preponderance of one sex in the population is because of the sexual difference in growth (Qasim, 1966).

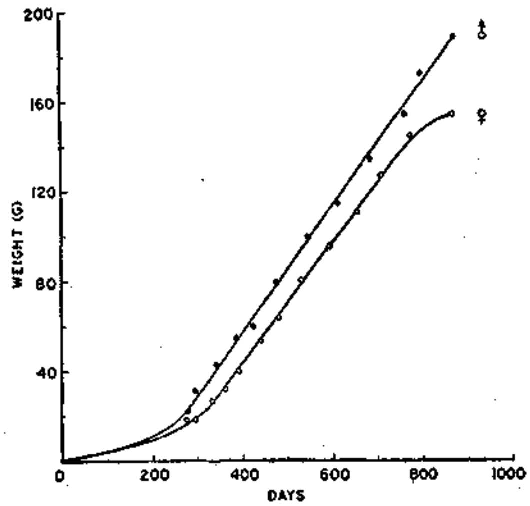

Fig. 2. *Panulirus polyphagus:* Mean increase in weight (g) of males and females reared in groups; each point represents the average of about 3 individuals.

The estimated average annual increase in weight was 47.24 g in males and 33.74 g in females during first year and 117.76 g in males and 111.26 g in females for the second year (Fig. 2). The percentage increase in weight of *P. polyphagus* at moults ranged from 8.8 to 44%. The percentage increase in weight at a moult decreased with increasing size of the lobsters. Travis (1954) and Fielder (1964) made similar observations for *P. argus* and *J. lalandei* respectively.

Fig. 3 shows the length-weight relationship in males and females. Weight is a function of length and is expressed by the equation $W = CL^n$, where W is the weight, L is the carapace length and C and n are constants. The mean CL and weight of the experimental males and females plotted graphically resulted in an exponential curve. The regression of log bodyweight (W in gram) on log carapace length was

$$\text{Male} \quad \log W = 3.14 \quad \log L - 3.45$$

$$\text{Female} \quad \log W = 3.71 \quad \log L - 4.3$$

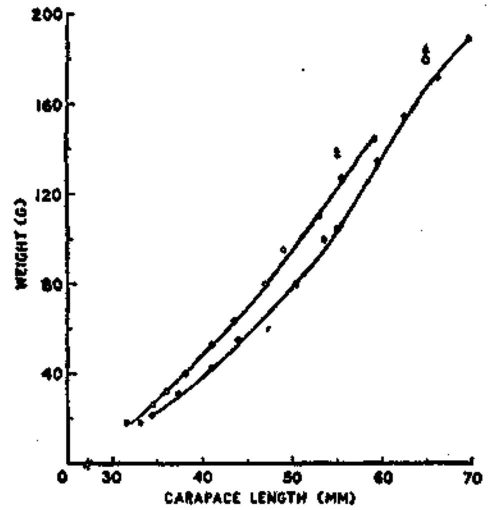

Fig. 3. *Panulirus polyphagus*: Relationship between carapace length (mm) and weight (g) of males and females; each point represents the average of about 3 individuals.

To understand the growth processes in lobsters, intermoult duration and moult increment were studied. The intermoult duration increased with age in both sexes (Fig. 4 a) and in males it was slightly longer than in females (52 and 45.5 days respectively). Though the females moulted 12 times and the males only 11 times in 800 days, females could attain only 60 mm CL, whereas the males attained 65 mm during the same period. Hence, the lobsters were not able to exhibit faster growth by shortening the intermoult duration. The increase in carapace length at moult (moult increment) was plotted against the number of moults (Fig. 4 b). Eventhough there was considerable variations in moult increment among individuals, as also noticed by Phillips *et al.* (1977), the mean moult increment in CL was higher for males (3.3 mm) than for females (2.6 mm). There was a gradual increase in the moult increment at successive moults in females for the first four moults, which thereafter fluctuated considerably. In males the moult increment in CL did not fluctuate much during successive moults; but the increment was clearly higher than the female except in the VI moult (Fig. 4 b). Hence the larger size acquired by the male at unit time was due to a higher moult increment in carapace length than shortened intermoult duration. The differential growth rate may also be due to deceleration of growth rate in females after attainment of sexual maturity resulting in an increasing divergence of the growth curves of males and females with increase in size (Berry, 1971). Morgan (1977) also found that in wild adult *P. longipes cygnus*, moult increment depressed with increasing size with adult males having a higher moult increment than females of the same size. Chittleborough (1976) observed that moult increment of males of the same species increased from ages 3+ to 5+ years, while those of the females did not very significantly between these age groups, and the moult increment of females was significantly below that of males.

The effect of temperature on frequency of moulting in palinurid lobsters has been studied in detail by earlier workers (Travis, 1954; Serfling and Ford, 1975; Phillips *et al.*, 1977). The prolonged intermoult duration in lobsters reared in groups in this experiment coincided with the fall in water temperature (Fig. 4 a, 4 c).

juveniles (upto an average of 30 mm CL) of *P. polyphagus* were observed to be gregarious and preferred to hide under shelter during day

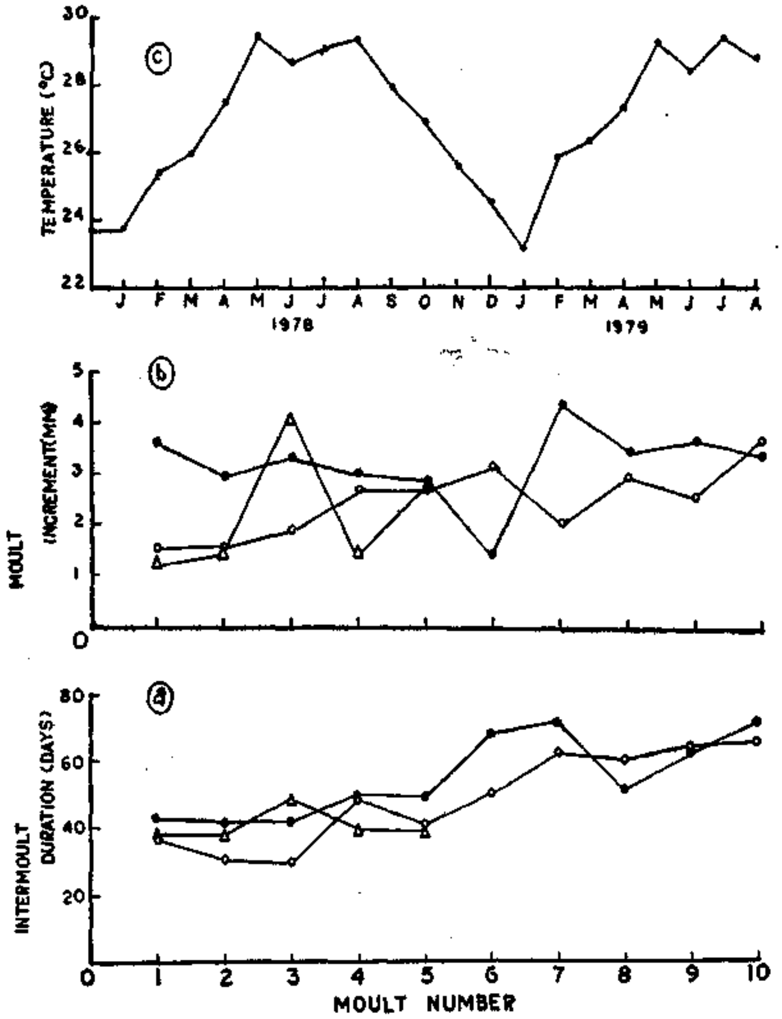

Fig. 4. *Panulirus polyphagus*: a. Mean intermoult duration against number of moults of male (●) and female (○) reared in groups of three. (△) represents the mean intermoult duration of three isolated individuals; b. Mean moult increment in carapace length against number of moults of male (●) and female (○) reared in groups of three. (△) represents the mean moult increment in CL of isolated individuals and c. Monthly mean water temperature in the laboratory during 1978 and 1979.

Effect of social pressure on growth

Social pressures influence moulting and growth in crustaceans as this is presumably a reflection of their gregarious or solitary behaviour in nature (Aiken, 1977). The early

time. The isolated individuals confined to the shelter during the commencement of the experiment; later they were foraging the bottom of the aquarium as they were acclimatized. *P. polyphagus* did not show significant difference in growth rate when reared in isolation or in groups (Fig. 5). The intermoult duration (Fig. 4 a) and moult increment (Fig. 4 b) were almost similar in both the series, but the isolated individuals did not survive beyond the sixth moult (*i.e.* after 525 days). Phillips *et al.* (1977) also found no significant difference in the growth of isolated and grouped individuals of *P. longipes cygnus* until they were 3 years old and Chittleborough (1975) reported depressed growth rate in isolation for the same species which were more than 3 years old.

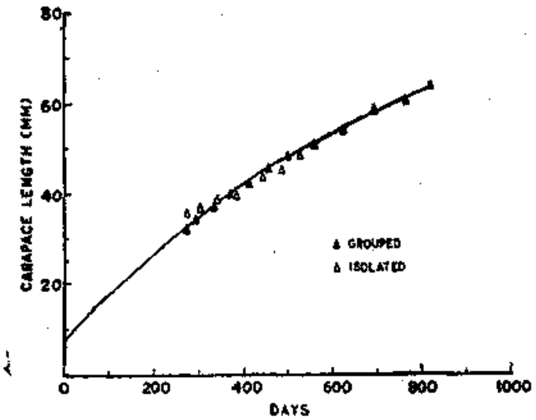

Fig. 5. *Panulirus polyphagus*: Mean increase in carapace length (mm) of grouped (▲) and isolated (△) individuals; each point of grouped series represents the average of about 6 individuals and that of isolated series 3 individuals.

Feeding behaviour during moulting

The animals stopped feeding 2-3 days before ecdysis; moulting took place mostly during night. The moulting pattern was similar to other palinurid lobsters (Travis, 1954). After moulting the animals were inactive and were hiding under shelter. Feeding commenced 2-3 days after ecdysis. The peak consumption of food was 5-6 days after moulting, which gradually reduced as the next moult was nearing.

Mortality

Mortality in the aquarium was about 30% in those reared in groups during the experimental period of 840 days whereas all the animals in isolation died within 525 days. The mortality was mainly during moulting when the carapace or walking legs were entangled in the old exoskeleton and the animals were unable to free themselves. Moulting abnormalities were also noticed in early juveniles. The antennae and the head folded-back interfering with the normal feeding of the animals. The lobsters below 25 cm CL autotomised limbs on handling, but it is uncommon in larger numbers of the species.

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PROSPECTS ON SPINY LOBSTER *PANULIRUS* SPP. CULTURE IN THE EAST COAST OF INDIA

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ABSTRACT

A method for collecting large number of pueruli and post-pueruli of the spiny lobster *Panulirus* sp. using different types of collectors suspended from a floating raft is described. Mangalore tile was found to be the best collector. For optimum collection of larvae the collectors should be suspended near the bottom.

The best season for collecting the larvae was from February to May. The abundance of the larvae has been correlated with the current pattern of the locality, the shoreward current wafting in large number of just metamorphosed larvae towards the coast for settlement on the bottom.

The larvae have been reared successfully to the adult in 18 months feeding on green mussels and backwater clams. The lobsters attained sexual maturity in closed culture system and spawned releasing millions of phyllosoma larvae.

Since the rearing of phyllosoma larvae to pueruli is beset with number of problems like the availability of proper type of feed at various stages of their complex life history, the culture of the spiny lobster for the present has to depend mainly on collecting and growing the naturally occurring pueruli and post-pueruli.

INTRODUCTION

LOBSTERS are highly priced sea-food for export from our country next only to prawns. During 1978, India exported about 690 tons of frozen lobster tails fetching foreign exchange to a value of 46 million rupees.

The total annual production of lobsters in our country during 1978 was about 1307 tons, Maharashtra contributing nearly 50% of the catch. Tamil Nadu contributed about 250 tons of lobsters to the total annual production. The lobster landings have shown a marked decline from 1975 onwards. The production could be increased by culturing them in confined waters.

Spiny lobsters enjoy a wide distribution and occur in rocky areas from Gujarat to Andhra Pradesh. Along the coast of Tamil Nadu *Panulirus ornatus* and *Panulirus homarus* contribute a major portion to the catch. *Panulirus versicolor*, *Panulirus polyphagus* and *Panulirus longipes* are also known to occur along the Tamil Nadu Coast. Kanyakumari area is the most important area for lobster fishing.

Not much work has been done in culturing the spiny lobsters in any country because of its complex life history. Deshmuk (1968) has studied the metamorphosis of *P. polyphagus* from puerulus to post-puerulus stage. Thomas (1972) has studied the growth of *Panulirus homarus* in captivity. Attempts at culturing them have been made in America, Japan, South Africa, Soviet Union and Australia. Scientists in Scripps Institute of Oceanography have kept the puerulus of *P. interruptus* in finger bowls for four moults. *P. elephas* has been successfully kept in aquaria and nursery ponds by Soviet Scientists. Japanese workers have reared *P. japonicus* for 5-10 months. Chittleborough (1974) has given an excellent review of prospects for rearing rock lobsters in Australian waters.

The present paper presents the results of work done at Madras in rearing spiny lobsters from pueruli to adult on a large scale and discusses the prospects for spiny lobster culture in India.

The fortuitous discovery by the authors of spiny lobster pueruli and post-pueruli occurring in large numbers on the mussel spat collectors suspended from the rafts in Covelong opened up a new avenue for investigation on lobster culture.

The authors are thankful to Dr. E. G. Silas, Director, Central Marine Fisheries Research Institute, Cochin for his encouragement.

Material and Methods

The Covelong Bay, where this work was carried out, is about 35 km south of Madras on the east coast road to Mahabalipuram. The bay is semicirculr and is guarded at its entrance by a series of rocky outcrops extending in north-south direction. A detailed description of the hydrological conditions, currents, topography, etc. has been given by one of us (Rangarajan, 1979) elsewhere.

A raft was floated at a depth of 8 metres and various types of collectors like Mangalore tile, plain as well as wound with thin coir rope, cut pieces of motor car tyres, bunches of frayed coir and nylon ropes, stringed coconut shells, etc., were suspended from the raft. The collectors were arranged at 6 metres, 3 m and 1 m depths. The collectors were lifted from the water daily and the occurrence of pueruli in the different collectors noted.

Results

The maximum number of pueruli and post-pueruli were collected from Mangalore tiles suspended at 6 m depth. Collectors at 3 m depth yielded only a few pueruli and those near the surface almost nil. This clearly showed that the depth at which the collectors were suspended is very important to get the maximum number of larvae.

It was noticed that more number of pueruli occurred on Mangalore tiles closely wound with thin coir rope than on plain tiles. It is quite likely that the rope wound tiles provided ideal hiding places for the pueruli since they were found in the gap between the tile and the rope. Although a few pueruli were collected from other collectors like motor car tyres and coconut shells, most of the pueruli were collected from Mangalore tiles.

More pueruli were found on Mangalore tiles which have been immersed in sea water for some time and over which a settlement of barnacles, mussel spats, amphipods, etc. have taken place rather than on new tiles. It is quite likely that the pueruli and post-pueruli were attracted by tiles with settlement of these organism.

Season of occurrence of pueruli and post-puerul

The pueruli and post-pueruli of *Panulirus* spp. came and settled down in large numbers on the collectors from November to June, the maximum number being obtained during March/April. The occurrence of pueruli and post-pueruli of three common species of spiny lobsters during 1977 is given in Table 1. After April they became scarce with stray numbers occurring during May and June. The best time to collect the pueruli of spiny lobsters is from February to May.

There was a similar pattern of occurrence of pueruli in the following year also.

TABLE 1. *Occurrence of pueruli of different species of* Panulirus *during* 1977

Months	*Panulirus homarus*		*Panulirus ornatus*		*Panulirus polyphagus*	
	Pueruli	Post-pueruli	Pueruli	Post-pueruli	Pueruli	Post-pueruli
January ..	—	—	—	—	—	—
February ..	2	7	2	2	1	—
March ..	14	20	9	23	17	1
April ..	4	6	4	11	12	2
May ..	—	1	—	2	8	—
June ..	—	—	—	—	5	—
July ..	—	—	—	—	—	—
August ..	—	—	—	—	—	—
September ..	—	—	—	—	—	—
October ..	—	—	—	—	—	—
November ..	—	—	—	—	13	—
December ..	—	—	—	—	12	—

GENERAL CONSIDERATIONS

The panulirid lobsters have a very complex life history, breeding in inshore waters and completing the protracted and complex larval development in the off shore areas. They are at the mercy of the currents in the sea and seem to get widely dispersed. It is not clear how the larvae pass through a number of moults to complete the metamorphoses and finally reach the rocky shores to settle down in their natural habitat.

Factors influencing the occurrence of larvae

The phyllosoma larvae are planktonic and with their long hairy appendages are well adapted for transport by sea currents. Their occurrence seem to be closely related to the currents in the sea.

The direction of current in the Covelong Bay is influenced by the prevailing surface winds. During May-June when the southwest monsoon sets in on the west coast, strong winds blow towards the sea. The direction of the current in the sea now is from south to north. It continues to flow towards north till September. During October the north east monsoon generally sets in along the east coast and the direction of wind is from northeast to southwest. The current in the sea reverses its direction and flows from North to South.

The occurrence of pueruli and post-pueruli of spiny lobsters near the coast coincides with the southerly current in the sea. The phyllosoma after completing the metamorphosis in the open sea are transported towards the coast by the southward flowing current and start occurring on the tiles from November onwards. The process continues till April during which period the maximum number of larvae were collected. With the change of current direction in May the occurrence of larvae becomes insignificant and scarce. During June to September when the northward current is quite strong the larvae are absent in the coastal waters. It is interesting to note that the breeding season of the spiny lobster in the east coast coincides with the onset of the northward current. Breeders in the natural population are very common during May-August. The northerly current presumably carry the phyllosoma larvae to offshore areas where the complex life-cycle is completed and southerly current bring the back towards the coast where rocks are abundant for the final settlement of pueruli. Successful development and metamorphosis of the larvare probably require clear and high salinity water.

Prasad and Tampi (1965) reported that the phylosoma larvae were scarce at the surface with a maximum concentration at about 50 m. The number generally decreased with increasing depth and most of the larvae obtained from the deeper waters *i.e.* below 1000 m were of palinurid lobsters. They pointed out that the concentration of larvae in upper 100 m seemed to be related to the distribution of pycnocline which acted as an effective barrier for the vertical movements of the larvae.

They were of the opinion that in spite of the prolonged planktonic life (6 or 7 months) the larval population were retained in restricted areas to accomplish restocking of the areas and have cited Johnson and Brinton (1963) in support of this opinion. Johnson and Brinton assume that the larvae which swim from one depth to another during vertical migration under the directive stimulus of light may conceivably spend a good deal of time alternatively in currents flowing in different directions or at different speeds. In this way a retardation or prevention of the wholesale outwash is effected. According to this assumption for a weak swimming planktonic larvae like phyllosoma to remain in a restricted area there should not be an unidirectional current for a long period. Such is not the case in the sea since the currents usually flow for a considerable time, sometimes for a couple of months, in the same direction. It is more likely that the larvae are drifted by the currents for a considerable distance away from the shore since they have been recorded at greater depths beyond the shelf. The larvae of the spiny lobsters of Western Australia are known to be carried by currents hundreds of miles into the open sea. The occurrence of larvae even at the depths of 500 m or 600 m clearly showed that they have been transported by the currents. At what level the larvae are carried to far away places is not clear. Their distribution and occurrence is intimately connected with the current pattern of the locality and unless the current pattern is studied in detail and extensive collection made it is difficult to get a clear picture.

Growth of pueruli to adult

The pueruli and post-pueruli were held in large polythene basins containing pure sea water. Aeration was also provided. The pueruli do not feed in the laboratory on the first day. Within a day or two they moult in the laboratory and become post-pueruli when patches of colour appear on the body. The post-pueruli and the juveniles were fed to satiation point with the fresh flesh of green mussel *Perna viridis* or backwater clam *Meretrix casta.* They readily take the fresh mussel flesh and show a preference to it over the clam flesh.

The growth of the spiny lobster *Panulirus polyphagus* from pueruli to adult for over two years has been studied by Radhakrishnan and Devarajan (1979). They have found that the annual growth rate was 34 mm in carapace length for male and 28 mm for female during the first year and 20 mm for male and 20.5 mm for female during the second year. It was found that in captivity the male grew faster than the females and the females attained maturity at an average carapace length of 48 mm. The estimated average annual increase in weight was 47.24 g in males and 33.74 g in females during the first year and 117.76 g in males and 111.26 g in females for the second year.

Prospects of Farming Lobster

Lobsters are quite hardy and able to withstand lot of environmental stress during culture. At Covelong it has been possible to rear the lobsters with little mortality or cannibalism for the past three years.

In a closed system of culture as practised at Covelong, a strict feeding schedule had to be maintained. Feed was given in the late evening and the unconsumed food removed in the morning lest it should contaminate the water by decay. It has been possible to culture the lobsters successfully in this closed system where water was changed only once in 2-3 weeks.

For the first time in India large number of pueruli have been collected at Covelong and reared to marketable sizes in about 18 months. They have also attained sexual maturity and spawned in the laboratory releasing millions of phyllosoma larvae.

Scientists at Covelong are engaged in breeding the spiny lobsters and rearing the phyllosoma larvae to pueruli in the laboratory in an effort to produce the seed required for large scale culture. They have met with partial success and been able to rear the larvae upto stage V in 60 days feeding with the naupli of the brine shrimp *Artemia salina.* Till this venture succeeds lobster culturists for some years to come have to depend upon the seeds found in nature and there is an urgent need to assess the concentration and distribution of pueruli of spiny lobsters both along the east and west coasts of our country.

Feed and feeding schedule

Experiments at Covelong have shown that feeding with green mussels gave a good conversion ratio of 6 : 1 which is quite efficient. An integrated culture system for green mussels and lobsters is indicated where the large quantities of mussels produced by raft culture could be fed to the lobsters. With proper water management and cheap source of food having high conversion ratio, it is definitely possible to bring down the time taken to attain marketable size to about 12-15 months.

Assured supply of cheap food throughout the year is very essential for the successful management of lobster culture. Sometime, especially during the monsoon time, when fresh mussels and clams are not available for feeding the lobsters, feeding with trash fish have been tried, but the lobsters do not feed well on them. Moreover the fish contaminate the water very quickly. A pelletized feed consisting of fish meal, tapioca powder, mussel flesh, etc. are being tried and the lobsters readily accept them. Development of a cheap pelletized food, fortified with vitamins and minerals to meet the nutritional requirement of lobsters will go a long way in making their culture profitable and economical.

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CULTURE OF THE MUD CRAB *SCYLLA SERRATA* (FORSKAL) IN TUTICORIN BAY

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ABSTRACT

The present paper comprises the results obtained in the experimental culture of the mud crab *Scylla serrata* in different types of cages in shallow bay of Tuticorin during 1978-79. The seeds were collected from estuarine area along creeks with its coastal mangrove swamps and impoundments and intertidal flats in and around Tuticorin. The young crabs were reared first in basket type cages made of cane splits for 2-3 months. Box type cages made of soft wooden planks, each comprising 8-10 compartments and metal framed synthetic twine mesh cages with compartment were preferred for culturing the grown up crabs. The crabs were fed with trash fish, clam meat and gutted wastes of the fish market. The growth rate of mud crabs in the existing environments appeared to be good as a good number of the stock moult frequently at an interval of 25-50 days. They were observed to reach marketable size through four—five moults in a period of 9-10 months. Eye stalk ablation accelerated the growth rate in young crabs and promoted gonadal maturation in adult crabs. Breeding behaviour of this species was observed and discussed in brief.

INTRODUCTION

THE MUD CRAB *Scylla serrata* constitutes a very important crab fishery in the whole Indo-Pacific region. Rao *et al.* (1973) evaluated the crab fishery resources of India and revealed the scope for developing the fishery into a major industry. Farming of suitable varieties of crab like *S. serrata* is an essential prerequisite for expansion as it is common to see the berried females being extensively fished in certain parts of the country and sold in markets for a high price. With increased culture activities envisaged in the overall development of the crustacean fishery, crab culture would naturally receive great attention. In addition to the increasing demand for protein food and for frozen crab meat for export it has become necessary to develop culture techniques for this neglected fishery. Available information on the biology and fishery of this edible crab have been enlisted by George and Rao (1967). Experiments to rear larval stages to juveniles have been conducted in Malaysia (Ong, 1966 a, b), India (Raja Bai Naidu, 1955), Sri Lanka and Philippines (Arriola, 1940) with varying degrees of success. Suitable techniques for application in culture field requires to be evolved. Of late, attempt has been made to culture the young ones to marketable size on moderate scale in Philippines (Escritor, 1970; Pagcatipunan, 1970), Thailand (Vanich varikul *et al.*, 1970), Sri Lank a (Raphael, 1970), India (Marichamy, 1979), Singapore and Taiwan. Taking advantage of the existence of intertidal mud flats in Tuticorin Bay and Karapad Creek with its coastal mangrove swamps and impoundments which serve as natural nursery for mud crabs, two sets of experiments relating to the culture of *S. serrata* in different types of cages were aimed at finding out the possibility of rearing young crabs to marketable size.

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Material and Methods

The young crab stages in the natural habitat remain as the only source of seed stock for the culture of this species. Seeds were available throughout the year and collected by using hoop nets baited with gill rackers and other gutted wastes. Width-weight a measurements and sex of the seeds were noted while stocking. Moult increments were recorded on the second day after moulting. Cages were periodically cleaned with stiff brush to avoid algal growth and colonisation of foulers. The first experiment was carried out during August 1978-December 1978 and the second during October 1978-April 1979. Crabs were cultured singly in different types of cages in order to avoid loss of stock due to cannibalism. Basket type cages made of cane splits were preferred for rearing young crabs. The grown up crabs, measuring above 110 mm (carapace width) were shifted to box type wooden cages or metal framed synthetic twine mesh cages. The basket type cages were suspended by means of coir rope tied to poles and always submerged in sea water. The other cages were placed on the racks erected in the creek. The dimensions of the cages were $2 \times 1 \times 0.3$ m and $1 \times 1 \times 0.3$ m with compartments at 0.3 m^2 each. Operation details of these cages had been already described by the senior author (1979). The pointed tip of the movable finger of the chelipeds of the seed crab was cut by using a bone cutter to minimize the possible damage to the basket. For observing the breeding behaviour of the crab five pairs of matured crabs were reared separately in big sized wooden cages. Eye ablation technique was adopted in crabs belonging to different size groups. Crabs were fed with bits of trash fish and clam meat. The left over food were removed periodically from cages.

Observations and Results

Experiments

Experiments were initially carried out at Karapad Creek (Pl. I A-C) where a good flow of tidal water existed. The depth was 1 m and during low tide the cages were partly exposed. Cleaning and feeding works were attended at this favourable time. 180 males and 160 females belonging to different size groups were collected and stocked in suitable cages during August 1978. About 52 per cent of the stock belonged to the size 7-9 cm carapace width (Table 1, Pl. 1 D). The average weight of the bulk of the stock was found in the range 65-141 gr. During early September 1978 the salt manufacturers barricaded the creek mouth preventing free flow of water in the creek in order to attend to some salt pan repair works. Consequently a change in the chemical and physical quality of water was noticed which ultimately resulted in the mortality of stock. The salient hydrological factors of the area of culture were recorded and presented in Table 2. Escritor (1970) observed a greater death rate due to high temperature at certain times of the day due to shallowness. In the present observation, due to increased salinity and temperature and stagnancy of shallow water of the creek nearly 53% of the stock perished by the end of September 1978. Subsequently, the cages were shifted to the inshore coastal water of the bay where further experiments were continued (Pl. II A). Crabs cultured in the fabricated cages were subject to mortality, particularly after moulting when the animal remained completely quiescent. Predatory fishes in the area bite the crabs through the meshes of the cage. The second experiment was carried out in the inshore water of bay with limited animals belonging to 3 distinct groups and the results are presented in Table 3.

Growth

The damaged fingers of the chela or the missing chelate legs noticed in some specimens

TABLE 1. *Details of* Scylla serrata *stocked in cages on* 9-8-1978

Carapace width cm	Male			Female			Average wt. gr.	
	No.	%	Wt. gr.	No.	%	Wt. gr.	Male	Female
3	5	2.9	40	5	3.2	39.5	8.0	8.0
4	7	3.9	92	5	3.2	65.0	13.2	13.0
5	20	11.1	620	15	9.3	445.0	31.0	29.9
6	21	11.7	1049	18	11.2	833.0	50.0	46.3
7	25	13.9	1893	20	12.5	1300.0	75.7	65.0
8	28	15.5	3083	25	15.6	2482.0	110.0	99.5
9	40	22.2	5671	40	25.0	5657.0	141.8	141.4
10	17	9.4	3745	15	9.4	3087.0	220.3	205.8
11	10	5.5	2714	12	7.5	3174.0	271.4	264.5
12	7	3.9	2398	5	3.1	3392.0	342.5	339.9
Total ..	180			160				

TABLE 2. *Hydrology of the crab culture area*

Place	Month	Surface temperature (°C)	Oxygen (ml/L)	Salinity (‰)	pH
Karapad Creek	June 78	25.7	4.1	36.14	8.00
	July 78	26.5	4.6	36.86	8.10
	Aug. 78	26.5	4.4	36.61	8.15
	Sept. 78	27.5	4.5	41.67	8.20
	Oct. 78	25.5	4.7	39.90	7.95
	Nov. 78	25.0	4.0	36.86	8.00
	Dec. 78	25.5	4.5	31.56	8.05
Tuticorin Bay	Sept. 78	26.0	4.5	36.52	8.15
	Oct. 78	26.1	5.9	36.98	8.00
	Nov. 78	23.5	3.4	31.00	8.10
	Dec. 78	25.0	5.0	27.89	8.05
	Jan. 79	25.2	4.7	31.56	7.95
	Feb. 79	26.2	4.9	33.95	8.00
	March 79	27.0	5.0	34.52	8.15
	April 79	28.8	4.5	34.08	8.00

Time of observation : 0900 hrs.

TABLE 3. *Details of* Scylla serrata *cultured in Tuticorin Bay from* 4 *October* 1978 *to* 3 *April* 1979 (6 *months*)

Size groups mm	Stock				Size groups mm	Harvest			
	Nos.	Average cw mm	Total wt. gr.	Average wt. gr.		Nos.	Average cw mm	Total wt. gr.	Average wt. gr.
51-59	20	55.3	498.0	24.9	118-129	18	122.0	5941	330.1
61-69	20	64.7	960.0	48.0	135-146	17	138.8	8792	517.2
72-79	20	75.1	1423.0	71.2	137-149	17	143.5	11069	651.1

Survive rate 89.7% gained wt. 22.9 kg

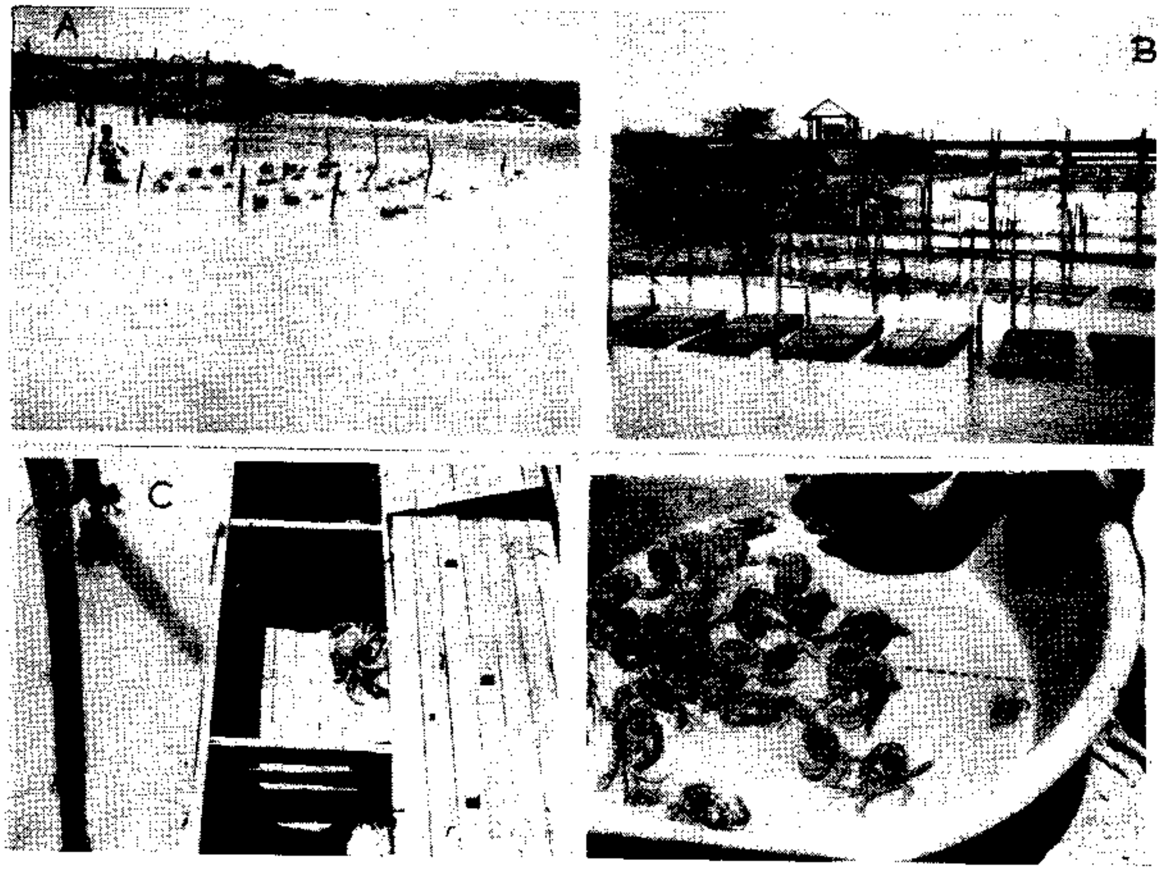

PLATE I. A. Young crabs cultured in baskets; B. Grown up crabs cultured in box type wooden cages; C. Crabs in compartments with lids open showing the feeding holes also and D. Part of seeds collected from the wild.

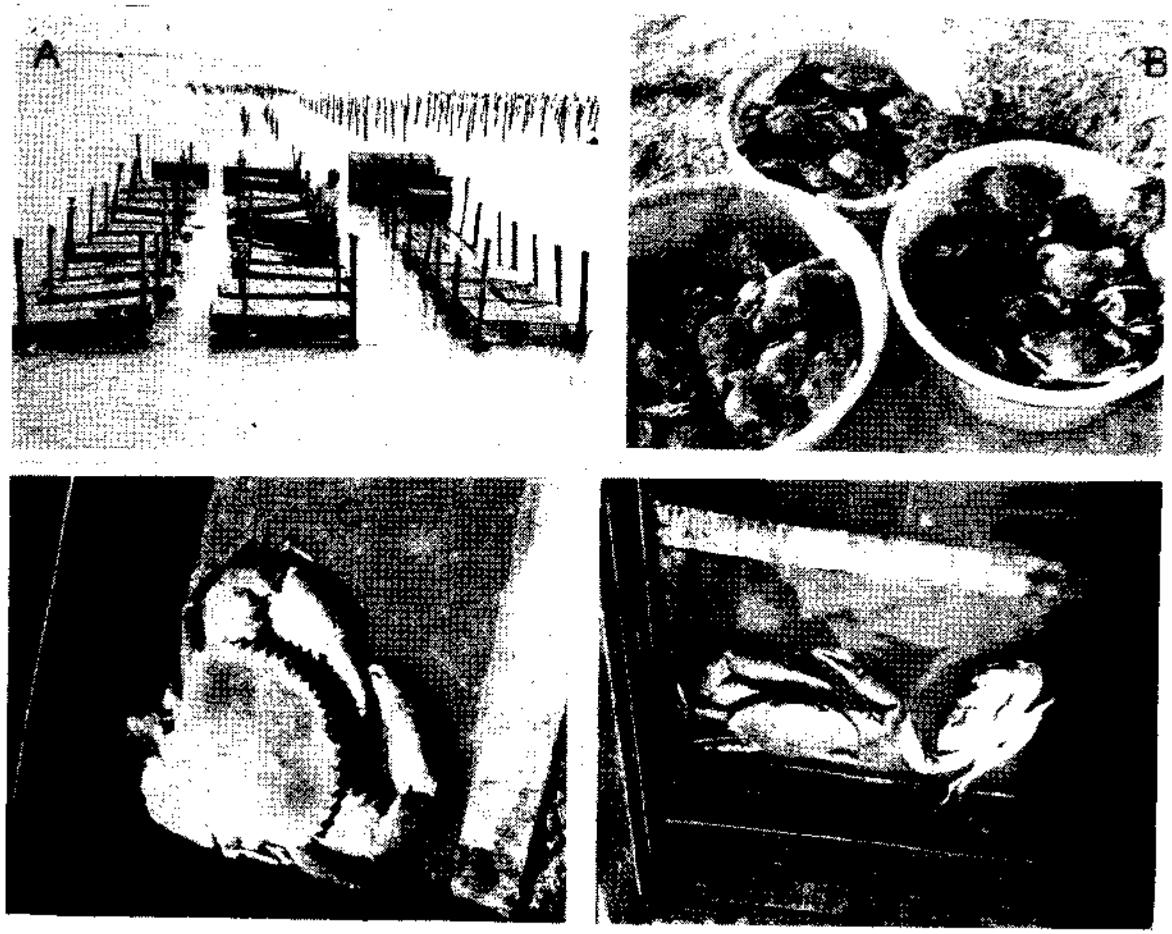

PLATE II : A. Box type wooden and fabricated cages in the bay ; B. Harvested crabs ; C. Crabs during mating and D. The pair separated. Female still lying on her back.

at the time of stocking regenerated in the subsequent moulting. Growth occurred normally when the shell was cast. Further increase in carapace width appeared to cease after the fourth or fifth day of moulting till the next moult. Moult increment and moult frequency were noted for every individual of the stock in growth study. In the process of moulting a split developed between the epimera and the inturned edge of the carapace along the pleural groove. The split gradually enlarged until the carapace was freed from the abdominal part of the exoskeleton. Thereafter with the muscular action the abdomen and the walking legs freed individually. Chelae were the last of the appendages to be withdrawn from the old exoskeleton. The actual period of moulting lasted for 30-40 m and most of the moult during night.

The young crabs measured less than 100 mm cw exhibited a stimulus to eye ablation and resulting in two frequent moulting ranging from 10-15 days. The moult increment in such crabs varied from 7 to 10 mm. Crustacean eye stalks contain the centres for distribution of gonad and moult inhibiting as well as accelerating harmones. Eye stalk ablation technique was also followed to induce precocius maturation of the ovary and subsequent spawning in captivity. Two female crabs at the size 104, 115 mm were selected for this observation. Only one eye was ablated. After an interval of 30 days they died. When dissected, the ovary was in fully matured condition having bright orange-red colour. A female berried crab collected in the size 125 mm cw was also put under this observation. On the fourth day, the animal released undeveloped eggs instead of attaching to pleopods. In the technique of eye ablation, a thick burning incense stick was used to puncture the eye ball.

The monthly average growth increment in size and weight of the crab of different size groups were plotted in Fig. 1. Individuals of the same size showed a difference in moult frequency and moult increment (Table 4). It can be observed from Fig. 1 that the rate of growth in size steadily increased and the maximum of 11.6-13.3 mm per month was obtained in the case of harvested male crabs measured under 10.0 - 12.9 cm carapace width. Females grouped under 10.0 - 13.9 cm cw exhibited a slightly low rate of growth ranging from 11.2 to 12.6 mm/p.m. In both the sexes the rate of growth in size remained minimized after reaching 14 cm cw. However, increment weight of the animal was steady and adult crab gained more weight as they grow.

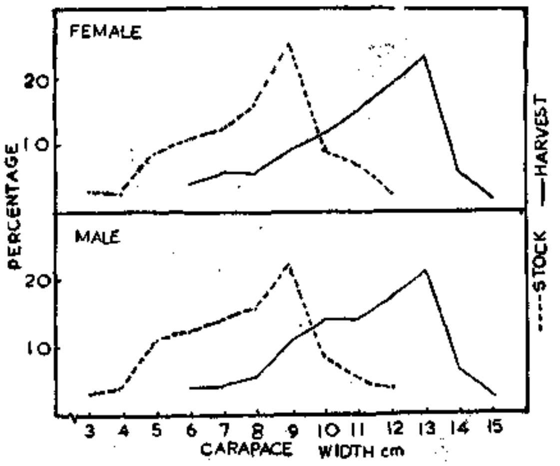

Fig. 1. Length frequency distribution of *Scylla serrata* cultured in cages.

In Fig. 2 the length frequency distribution of cultured crabs both at stock and harvest has been depicted. The peak size group observed at 9 cm progressed to 13cm thus indicating an overall growth of 4 cm in 4 months. The average weight of this group of crab varied from 450 - 460 g. Males exhibited greater increase in weight than the other sex because of the fleshy chelae.

Production

The area utilized to carry out the present experiment in cages was 200 m². Out of 340

TABLE 4. *Growth particulars of* Scylla serrata *harvested on* 5-12-78

Sex	Carapace width cm	No. of crabs	%	Increase in carapace width mm min.	Increase in carapace width mm max.	Total wt. gr.	Average wt. gr.	Increaee in weight gr. Min.	Increaee in weight gr. Max.
Male (72)	6	3	4.2	7.8	9.1	151	50.3	9.9	12.7
	7	3	4.2	9.1	10.4	279	93.0	20.8	22.4
	8	4	5.5	9.6	11.2	474	118.5	22.4	29.9
	9	8	11.0	9.9	11.2	1226	153.3	29.6	33.3
	10	10	13.9	10.4	12.7	2409	240.9	47.6	62.4
	11	10	13.9	12.2	14.3	2833	283.3	52.0	71.5
	12	12	16.8	11.2	13.0	4649	387.4	61.8	91.8
	13	15	21.8	8.3	11.4	6862	457.5	58.2	101.4
	14	5	6 .9	6.5	8.6	2894	578.8	61.9	106.1
	15	2	2.8	6.0	7.3	1545	772.5	103.4	104.0
Female (53)	6	2	3.8	8.6	9.3	95	47.5	10.4	—
	7	3	5.7	8.8	10.4	254	84.7	15.8	20.8
	8	3	5.7	8.8	10.9	338	112.7	21.6	25.2
	9	5	9.4	10.1	10.9	739	148.0	28.9	32.8
	10	6	11.4	11.2	12.2	1426	237.7	33.5	56.9
	11	8	15.0	12.1	13.3	2203	275.4	56.4	60.3
	12	10	18.8	11.4	13.3	3832	383.2	67.1	97.2
	13	12	22.6	10.9	11.4	5424	452.0	70.2	95.7
	14	3	5.7	9.4	9.6	1680	556.0	93.9	98.0
	15	1	1.9	8.3	—	715	715.0	101.8	—

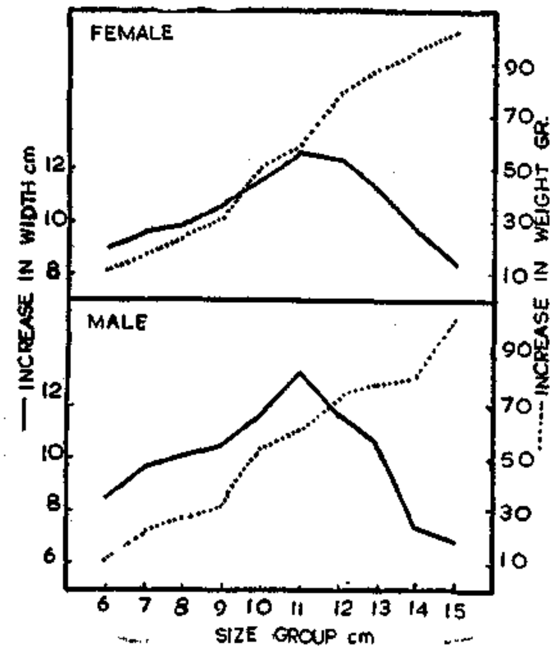

Fig. 2. Average growth increment of *Scylla serrata* in different size groups.

crabs stocked, only 72 males and 53 females were recovered after a period of four months and these together weighed 40 kg (Pl. II B). This increment was from the initial stock of seeds weighing 15.36 kg. Among the harvested crabs the total gain in weight was 160.6%. The rate of survival was accounted to be 36.8 per cent. At this rate, the production potential per hectare worked out to 2000 kg in 4 months. An increase in the yield was obtained in the second experiment when the cages were placed in a submerged level where better environmental conditions prevailed. The depth of the ground was 2-3 m. The survival rate improved to 86.7% and in a period of six months the weight of the crabs increased from 2.9 kg to 25.8 kg.

Mating behaviour ; A series of observations on the mating behaviour of mature crabs in the size 100-130 mm cw were made. The act of copulation was seen and photographed (Plate II C-D). Once attracted to a female the male showed on attraction to food and remained continuously with the female. Pairing was found to occur for period ranging 3 days before the moult and for a further period of 1-2 days after moult. During the premating embrce, the male climbed over and clasped the female by his chelipeds and the anterior pair of walking legs. The pair separated on the verge of precopulatory moult. After the copulatory moult of the partner the male gently turned the female over her back using the chelae. The female unfolds her abdomen, co-operating in this behaviour actively to held the male into position. These observations suggest that moulting and increase in size would continue in both sexes including those which have attained maturity. The mated females were reared in the same environment for oögenesis and ovulation to take place, since the berried females are normally found in sea and not in brackishwater. Two of these mated female crabs in the size 101 and 110 mm died after 50 days, but none had become egg bearing and no development of the gonads was seen to have taken place when the crabs were later dissected. It can be stated that in *S. serrata* mating can take place without subsequent egg carrying. Edwards (1966 b) found similar features in *Cancer pagurus*. Ong (1966 b) observed such condition in crabs at size 116.9 mm and explained that copulation may occur in female *Scylla* before the stage of full sexual maturity. The present findings also confirmed that the individuals of a species generally do not mature at the same age or size.

Discussion

The influence of salinity on growth of crab was studied to some extent by earlier workers. According to Ong (1966 b) the intermoult period was shorter for immature crabs reared in water of reduced salinities. Alice (1979) found that at 26 ppt lesser moults occurred with increment in weight and more moults at 30 ppt with lesser overall weight increments. In the area of present experiments the salinity was higher than 33 ppt except the north east monsoon period when it fluctuated from 27 to 31 ppt and an overall weight increment was well noticed. The percentage moult increments were greater for young crabs and decreased in the later stages. The time interval between consecutive moults was greater with adult crabs. Ong (1966 b) observed a higher rate of average moult increment *i.e.*, 10.7-14.6 mm with the crabs of mean carapace width ranging from 70-100 mm and in the crabs measured above this size the growth rate was reduced. Escritor (1970) recorded an average growth increment of 17.2-17.6 mm cw with the crabs stocked in the size 79-97 mm. However, in the present study a fast rate of moult increment (11.2-13.3) was found in slightly big sized crabs belonging to 10-16 cm. Vanich varikul *et al.* (1970) observed a difference in the rate of survival and gain in total weight of the crabs by reducing the period of culture from 60-45 days. Escritor (1970) did not notice any difference in the growth increment in the crabs cultured with intensive feeding and shorter rearing period to that of the longer rearing without supplementary feeding. In the present observation the aim was to obtain crabs of high quality and large size and hence the period of culture was extended to gain weight in the harvested crabs to a maximum of 160 per cent. Although the magnitude of the rearing experiment was low, the results of the observations envisage the scope for an extensive culture in this area. With the increasing attention shown in different Southeast Asian countries, mass culture of crabs would become in near future as practicable as the culture of other decapods, like prawns.

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A CULTURE EXPERIMENT ON THE CRAB *SCYLLA SERRATA* (FORSKAL) AT TUTICORIN DURING 1975-77 TO ASSESS GROWTH AND PRODUCTION

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ABSTRACT

The green crab *Scylla serrata* is commercially the most valuable in India, with great potentialities for large-scale culture operations. In fact, experiments are being carried out in some southeast Asian countries for evolving a technique suitable for the pond culture of this burrowing and cannibalistic species. The present paper gives an account of an experiment undertaken at Veppalodai, Tuticorin during 1975-77, by rearing in individual plastic cages, for ascertaining their survival, growth and production with artificial food supplied. The results obtained from this exercise are highly encouraging with regard to survival, growth, production, etc. The present paper deals with the above work and the results obtained, along with suggestions for evolving a culture technique for pond culture of this species.

INTRODUCTION

THE GREEN CRAB *Scylla serrata* is widely distributed in the Indo-Pacific region and among the crabs occurring in the coastal waters of India, both in the seas and estuaries, it is the most highly valued species commercially. Rai (1933), Hora (1935), Chopra (1939), Jones and Sujansingani (1952), Chhapgar (1962), Thomas (1972), Datta (1973) and Rao *et al.* (1973) have dealt with the fisheries of this species in different parts of the subcontinent. In view of its euryhaline nature, capacity to live outside water for a few hours, feeding on a variety of cheap animal food such as trash fish, butcher's waste, etc. quick growth rate and increasing market demand, it is considered as one of the most suitable marine resources for coastal aquaculture operations. Realizing the potentialities for its culture, attempts are being made in the Indo-Pacific region for commercial culture and propagation of this species (Escritor, 1972; Pagcatipunan, 1972; Varikul *et al.*, 1972; Grino, 1977; Lavina, 1977). In India also, as an integral part of the mariculture programme of the Central Marine Fisheries Research Institute, an experiment was undertaken during 1975-77 in the salt pan areas at Veppalaodai near Tuticorin, for assessing growth, production and possibilities of its culture; and the results obtained in the experiment are recounted in the present paper.

The author wishes to express his deep sense of gratitude to Dr. E. G. Silas, Director, C.M.F.R.I. for the kind help and encouragement given in the execution of the above project as well as to late Dr. K. V. Sekharan for the suggestions given in the improvement of operations carried out.

METHOD OF CULTURE

A pond measuring 22.75 × 12.25 m in area (Pl. 1 A) at the marine fish farm in the salt pan areas at Veppalodai, about 25 km north

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of Tuticorin was selected. Nair *et al.* (1975) have given an account of the salt pan areas at Veppalodai and Bensam and Marichamy (unpublished) have dealt with the lay-out of the fish farm constructed there, mode of water supply to the ponds and the general hydro-biological conditions in the farm site.

The depth of the pond ranged from 50 cm to 70 cm. As this species has the capacity to live out of water for appreciably long periods during which they are likely to move out of the culture pond by burrowing through or crossing over the earthern bunds and as they are cannibalistic in habit, it was decided to rear the crabs in individual plastic cages in the pond. The cages selected from various types available in the market were circular, 24 cm in diameter, 12 cm in height and provided with a lid each. Except at the bottom they were perforated, each perforation of 5 × 5 mm in extent along the sides and 2 × 3 to 5 × 10 mm on the lid. The interspace between perforations were about 3 to 5 mm in width. Each crab was placed inside a cage and the lid was fastened tightly to the cage through the perforations with the aid of synthetic twines at first. However, it was soon found out that a few crabs have cut the twines within a few days and managed to open the cage and make good their escape. In view of this, galvanized iron wires were used instead of synthetic twines and the crabs were not able to cut them. The culture area for each crab thus cultured worked out to be 625 sq. cm and the stocking rate was 1,60,000 caged crabs per hectare.

The cages with crabs inside were placed at the clayey substratum of the pond and in order to prevent the cages being moved away and displaced by wind and flow of water, they were held in position by vertical ropes which were fastened to a horizontal line fixed across the pond and attached to two poles planted at opposite sides (Pl. I B). The seeds of *S. serrata* were collected from crab holes in and around Veppalodai itself and most of the seeds obtained were without one or both of the chelipeds which were broken invariably in the process of capturing the crabs. In the beginning stages of stocking some crabs stocked with both chelipeds intact were found to have destroyed the cages partially, obviously with the aid of their chelipeds and in a few cases they have made good their escape. In order to prevent this, the movable segment of the cheliped was amputated with a pair of scissors before stocking the crabs ; and this has successfully served to prevent the crabs from damaging the cages. Before stocking, all the crabs were measured for their carapace width, length and weight. They were fed with pieces of trash fish, clam meat, sea-weeds, etc. collected at Veppalodai, by introducing the food through perforations of the cage. The crabs were watched (Plate I C) every day for moulting, particularly around new moon and full moon days when the frequency of moulting is higher than the intervening days ; and in cases of moults, the crabs were measured and weighed soon afterwards.

Mortality and Survival

In the course of July 1975 to June 1977, 165 *S. serrata* were cultured in individual plastic cages at Veppalodai. Among these, eight crabs escaped during 1976 by damaging the culture cages and breaking the synthetic twines fastening the lid with the cage. Apart from this, 49 crabs died during 1976 and 27 in 1977. Of these mortalities, 7 crabs in each year were killed as a result of pumping high saline (100-140 ‰) water by Veppalodai Salt Corporation for supplying saline water for their salt industry. During 1976, four crabs died due to infestation of amphipods, invading and consuming the internal organs. As amphipods were found to establish easy access to the culture stock placed at the pond bottom, it was decided to keep the cages partly submerged in water by lifting them off and keeping in a suspended condition. This method as well as regular examination and

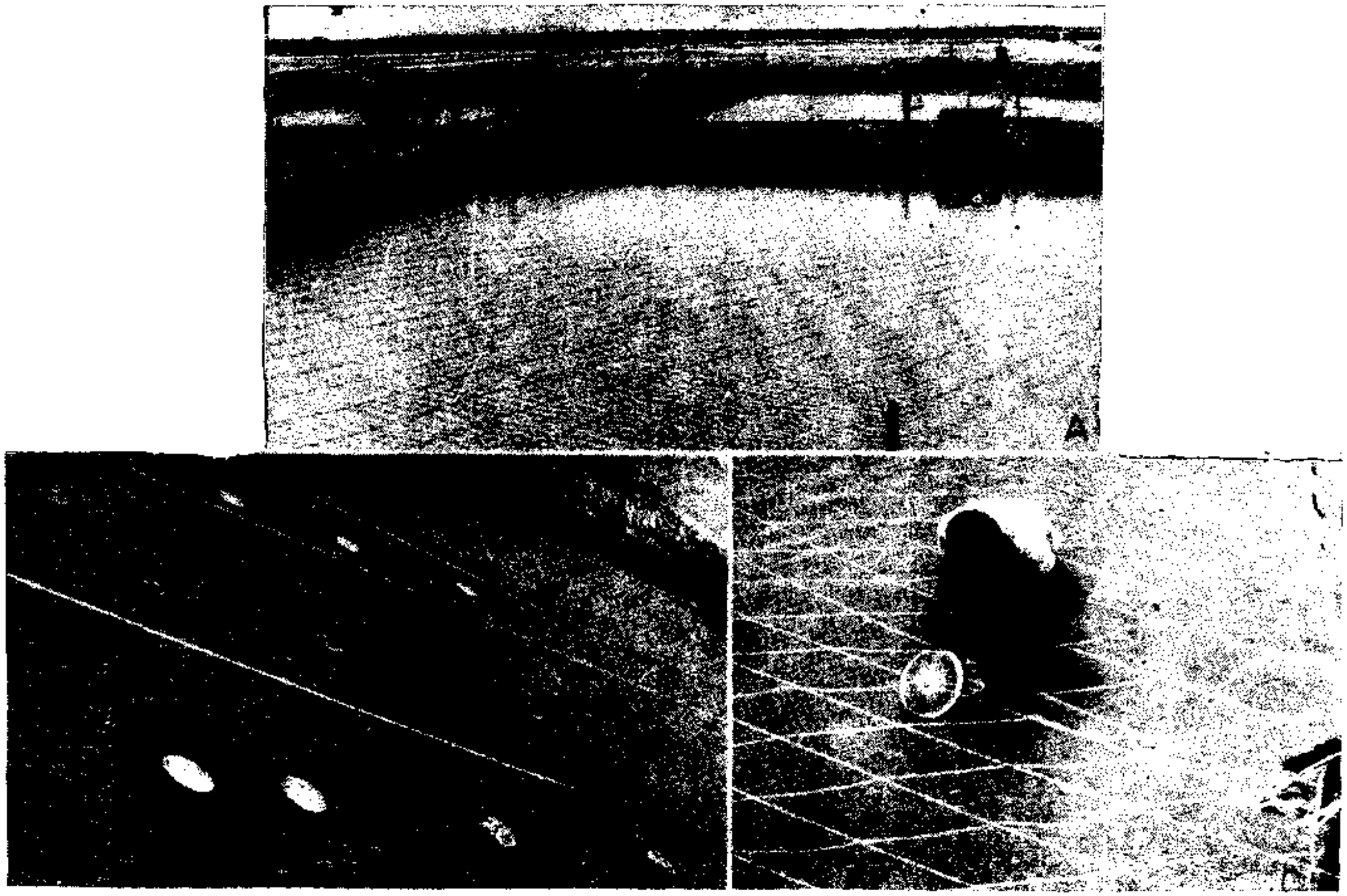

PLATE I. A. Marine fish farm at Veppalodai, Tuticorin, B. cages with *Scylla serrata* suspended in pond water and C. examination of cultured crab in the cage for moulting.

cleaning the crabs with a brush have served to reduce the mortality of the stock due to infestation of amphipods.

In addition to mortality caused by amphipods, three crabs were found to have died during 1976 due to excessive growth of certain filamentous green algae on their body, colonizing on the appendages as well as different regions including joints. From an examination of the dead crabs it appeared as though the green algal growth had arrested the growth as well as moulting of the crabs, affecting their physiology and leading to death. As in the case of amphipods causing mortality to crabs off bottom culture of the stock by suspending the cages as well as periodical cleaning and scrapping of algal growths have served to remove mortality from this factor.

Including deaths caused by amphipods and algal growth, the natural mortality suffered by the population in the course of the present experiment works out to be 38.78% and excluding the above two factors, natural mortality amounted to only 34.5% for a period of two years. It is obvious from this that the annual mortality of *S. serrata* in the present culture experiment ranges only upto a negligible proportion of 17.25% and the monthly rate is only 1.4%. As the crabs cultured in the cages were confined to a small area of only 625 sq cm, with a moving space of about 7,500 cu cm, it is obvious that the individuals were in a state of somewhat arrested condition. It is quite possible that if the crabs were afforded much more moving space for their normal activities as in pond culture, the present rate of mortality could have been reduced. Also, in their normal habits of movements here and there, the crabs could have escaped infestations of amphipods and algal growths.

GROWTH

The smallest crab stocked in the present experiment measured 26 mm carapace width (cw.), 18 mm carapace length (cl.) and weighed 3 gm. It was stocked in May 1977; and by July it had moulted three times and grown to 52 mm cw., 34 mm cl. and weighed 20 gm. Another crab stocked in May 1976 measuring 33 mm cw., 21 mm cl. and 6 gm in weight, lived for twelve months and in May 1977 measured 116 mm cw., 79 mm cl. and 225 gm in weight. A third crab with 37 mm cw., 23 mm cl. and 10 gm stocked in April 1976, survived for 15 months and measured 129 mm cw., 85 mm cl. and 395 gm. Crabs belonging to larger size groups cultured in the experiment have recorded much more growth. For instance, a specimen of 58 mm cw., 37 mm cl. and 30 gm stocked in March 1976 grew to 87 mm cw., 58 mm cl. and 95 gm in the course of six months; another crab of 80 mm cw., 55 mm cl. and 80 gm grew to 136 mm cw., 88 mm cl. and 320 gm by the end of twelve months ; and still another crab of 102 mm cw., 72 mm cl. and 205 gm, attained 128 mm cw., 85 mm cl. and 320 gm at the end of eight months. Apart from these normal modes of growth, some quick spurts of growth were also observed in a few cases, particularly in the initial one or two months. As an example, a crab of 113 mm cw., 75 mm cl. and 200 gm weight stocked in July 1976 was found to have grown in two month's time to 131 mm cw., 87 mm cl. and 318 gm in weight.

The mode of regeneration and growth of one or both chelipeds of the crabs cultured showed variations. In some cases where both chelipeds were amputated at the time of stocking, only a single cheliped was regenerated at first. For instance, in a crab of 93 mm cw., 61.5 mm cl. and 107 gm weight, both chelipeds were absent at the time of stocking in September 1975. At the first moulting of this crab in November 1975, only the left cheliped was found to have regenerated. At the second moulting in the following March, the right cheliped was also found to have regenerated.

As the chelipeds are substantially massive, containing a large proportion of meat, regeneration and growth of the chelipeds were found to and substantially to increase in the weight of the crab concerned. In the above case for instance, with the first moulting and regeneration of the left cheliped, the weight of the crab increased from 107 to 170 gm and with the subsequent moulting accompanied by regeneration and growth of the right cheliped also, the weight of the crab reached 202 gm, thus registering a net increase of 195 gm in the course of six months.

Production

The weight groups of *S. serrata* cultured in the present experiment in 50 gm intervals, the actual weight ranges of crabs stocked in each group with the mean weight and ranges of weight increments registered along with the mean weight are presented in Table 1. From Table 1 it may be seen that, but for a few cases of variations, there are steady increments in the weights of all the crabs cultured. In many cases of lower weight groups (young crabs), there were initial increases amounting to 1.5 times (as in 51-60 gm group) and 2.7 times (as in 1–10 gm group), within a period of one month. At the end of three months of culture period, the increase in weight ranged from 2.3 times as in 51-60 gm group to 3.5 times in 1-10 gm group. As growth progressed further, the weight increments were also found to become proportionately more, thus amounting to 2.5 times in 51-60 gm group and to 11 times in 1.10 gm group in the sixth month of culture as well as to 3.5 times in the former group and 17 times in the latter group in the tenth month of culture period. In still larger groups of crabs cultured, ranging from 61-70 to 111-120 gm groups, the rates of weight increase varied from 1.2 times to 1.5 times in the first month of culture and 1.3 to 2 times in the third month. In the nineth and tenth months of culture, the weight increments amounted to 2.4 to 3.1 times. In still larger groups, production appeared to range from 1.5 to 2 times the weight at the time of stocking.

The data available from the present experiment also indicates that in groups upto 50 gm, the monthly weight increase range from 8 to 17.8 gm, with average monthly increment at 16.15 gm for 12 months of culture. In the weight groups ranging from 51 to 100 gm, the monthly weight increase varied from 12.3 to 62 gm, with mean monthly increment at 14.7 gm (Table 1). The weight group from 101 to 150 gm showed monthly increases of 3 to 28 gm with the monthly average value at 19.6 gm. Taking into account all weight groups in the present experiment, the monthly average production of each crab amounts to 16.8 gm. During the culture period in the present experiment, each crab has occupied an area of 625 sq. cm and from this it may be stated that production every month from crab culture as under the present conditions could be expected to be of the order of 2,680 kg/hectare. This would work out to be 8,040 kg/ha for a three months period of culture, 16,080 kg/ha for a six months period and 32,160 kg/ha for a twelve months period.

Remarks

From the above, it is obvious that this crab can be cultured profitably yielding quite a good return within a period of 3 to 6 months or even one year. Experiments on the culture of this species have also been carried out in a few southeast Asian countries for sometime now. Escritor (1972) gives an account of its culture in a small pond in Philippines, fenced with galvanized iron corrugated sheats. The average growth increments extending four and six months there were 17.15 mm cw. and 13.15 mm cl. and 17.69 mm cw. and 12.87 mm cl. respectively. In the present case, crabs having comparable measurements have registered almost similar

TABLE 1. *Monthly weight increments of* Scylla serrata *and the mean values (in parentheses) in the culture experiments at Tuticorin in every 50 grams weight groups during 1975-77*

Group (Weight in Grams)	Minimum and Maximum weight increments recorded and the mean values (in parentheses) in grams after each month of culture																
	At Stocking	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th	11th	12th	13th	14th	15th	16th
1— 50	6-46.4 (26.2)	16.1-72.2 (44)	25.6-85.3 (54)	20.8-99.6 (61.7)	46.6-110.2 (71.5)	36.5-126.2 (79.9)	68.6-126 (95)	75-122 (103.6)	87.8-135 (110)	133 (133)	103.3-185 (142)	134-138 (136.6)	140-322 (220)	150-255 (206)	277.5 (277.5)	203 (203)	395 (395)
51—100	56.1-96.2 (75.9)	84.4-146.5 (115.4)	100.5-152 (127.8)	111.5-162 (135)	125-190 (158)	153.3-168.7 (161.2)	135 (135)	147-190 (180)	164.2-211 (175)	145-205 (145)	197-288 (237)	200-270 (238.6)	192-282 (224)	242-280 (261)	203-307 (238.3)	—	—
101—150	106-146.5 (127.1)	146-217 (180)	139-209 (175.8)	175-235 (203.5)	175-285 (229)	174.5-269 (232)	202-275 (245)	135-235 (185)	195-235 (204)	—	300.8 (300.8)	257 (257)	—	280 300 (290)	283 (283)	—	—
151—200	154-198.2 (177.1)	242-262 (252)	209-318 (263.5)	220 (220)	230-258 (239.3)	368 (368)	—	235 (235)	—	—	—	—	—	—	—	—	—
251—300	255-270 (262)	260 (260)	—	—	—	390 (390)	—	—	—	—	—	440 (440)	—	—	—	—	—

growth increments, ranging from 8 to 17 mm cw. and 6 to 12 mm c.l. and 15 to 20 mm cw. and 8 to 15 mm cl. in four and six months respectively. As a matter of fact, individual increments in sizes and weight did not appear to depend upon the passage of time alone Escritor (1972) records poor recovery rates in his experiment on culture of *S. serrata* and attributes them to difficulties in harvesting as well as to the boring, crawling and cannibalistic habits of the species. In a preliminary experiment on the culture of *S. serrata* in Thailand, Varikul *et al.* (1972) have obtained a production rate of 264 to 403 kg/ha for a culture period of 45 to 60 days and Grino (1977) reports a production of 200 crabs/ha/year in the milkfish ponds of Java. When compared with these figures, the present estimated production appears to be highly encouraging. Grino (1977) gives an account of the culture practices for *S. serrata* in Western Visyas in Philippines. The culture period there lasts for four to five months and the ponds are subjected to preparations for the growth of *lab-lab* and zooplankton on which the juvenile crabs subsist. As *lab-lab* thins out, supplementary food is given to the culture stock in the form of trash fish, etc.

One of the major problems encountered by culturists of *S. serrata* is their cannibalistic nature. A way of minimising cannibalism is the provision of adequate quantities of food for the stock. Also, in order to prevent one crab attacking another, the last segment of the cheliped may be amputated periodically or alternatively, the last two segments of the chelipeds may be immobilized by fastening with a metal wire. Another problem faced in the culture of this species is its burrowing habits and escape from culture ponds. In order to overcome this difficulty, it is advisable to erect corrugated iron sheets or asbestos sheets all along the sides of the culture ponds with sufficiently deep penetration into the pond bottom for preventing the crabs from burrowing through. Also, sufficiently tall asbestos or iron sheets would serve to prevent the crabs from crossing over.

Regarding the availability of seeds of *S. serrata*, adequate information is not available on the seed resources centres, seasons of collection, etc. It is obvious that in order to realise a successful culture industry for this crab it is imperative to locate its seed resources centres, as early as possible. Also attempts at artificial propagation of this highly euryhaline species could be made for providing a continuous supply of its seeds as is done elsewhere (Escritor, 1972 ; Lavina, 1977). By ensuring such essential prerequisites for the culture and propagation of this species, it appears quite possible to realise a production rate of upto 32,160 kg/ha/year, as estimted in the present experiment at Tuticorin.

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A TECHNIQUE FOR THE FIELD CULTIVATION OF A CARRAGEENOPHYTE *HYPNEA MUSCIFORMIS* (WULF.) LAM.

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Abstract

There is a growing awareness for utilizing the species of *Hypnea* for producing carrageenan in India. The available natural resources of this species being limited, there is a need to cultivate it in the Indian waters. Hence, a basic technique for the cultivation of *Hypnea musciformis* (Wulf.) Lam. in the lagoon of Krusadai Island has been developed. The species has been successfully cultured using the vegetative fragments as 'seed' material by the long line rope method and four-fold increase in biomass in 25 days has been achieved. After an initial rapid growth, the rate was found to decline beyond 7 days. Potentialities for the large scale cultivation of the species are discussed.

Introduction

Carrageenan is widely used the world over in food, pharmaceuticals and milk industries. It is produced from the species of *Echeuma*, *Chondrus* and *Gigartina* that are mostly represented in temperate waters. In India it has been found that *Hypnea* is a good source of carrageenan (Levring *et al.*, 1969 ; Rama Rao, 1977 a ; Parekh *et al.*, 1979). The biology of Indian *Hypnea* is well understood in recent years (Rama Rao, 1976, 1979 ; Rama Rao and Krishnamurthy, 1978). Since *Hypnea* natural resources on the Indian Coast are very limited for supporting the industry, its artificial cultivation in the Indian waters will be promising. Hence, preliminary experiments were carried out at Krusadai Island to develop a basic technique for its cultivation and the results form the subject matter of this paper.

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Material and Methods

Hypnea musciformis mostly inhabits small coral stones in the lagoons of the off-shore islands in the Gulf of Mannar in Tamil Nadu. A suitable area (120 sq.m) for the experimental cultivation was selected in the lagoon on the south side of Krusadai Island. 20 bamboo poles were fixed, lengthwise at a distance of 10 m and breadthwise separated by 1 m. One inch thick coir rope served as the substratum. The long-line method of planting (Raju and Thomas, 1971) was employed in which 4 cm fragments from freshly collected *Hypnea musciformis* were inserted into the coir twists at intervals of six inches. In all 1.5 kg fresh material was used for planting in 150 m of rope. The ropes were tied to the poles at a level of 0.5 m above the bottom so as to prevent soil abrasion. From the date 30-8-1979, of experiment, growth of the plants in general and the spread on the rope were followed at frequent intervals. Growth was recorded at weekly intervals, and one harvest was taken after 25 days growth, after ascertaining maturity of the plants. The culture ropes were kept free from the contamination of other organisms and silt by periodical weeding and cleaning. After the harvest, the experiment was continued upto December 1979. However, as no appreciable growth took place, further harvest could not be made.

RESULTS

The growth of fragments started immediately by the production of branch laterals some of which were modified into tendrils. And by means of the latter the growth quickly spread to the sides and in a few days the entire rope seemed to have been covered with the growth of the seaweed. The growth in length was generally uniform and was recorded at random from all over the rope. The plants attained 20 cm in 25 days some of which showed indication of being lost due to wind and wave action. A harvest was made after 25 days by hand-picking leaving behind 4 cm fragments to serve as the 'seed' material for further growth. The growth in length and harvest data together with the growth rate in biomass are given in Table 1. The growth rate showed a steady rise exponentially upto 14 days, reaching a maximum of 5g/g/day (wet) in 25 days

TABLE 1. *Growth and harvest data of* Hypnea musciformis *in culture at Krusadai Island in* 25 *days* (31.8.1979 *to* 25.9.1979)

Date	Growth in length (cm)	Biomass (harvest) Kg/entire rope (fresh)	Growth ratio in biomass g/g/day
31-8-1979	4	1.50	*..
7-9-1979	11	..	..
14-9-1979	18	..	..
25-9-1979	20	6.34	4.2

* Initial date at the time of planting.

(Fig. 1). That is, the growth was resumed immediately without going through any lag phase. In certain cases the plants measured upto 28 cm which was also the level of maximum height of the natural plants. In all a

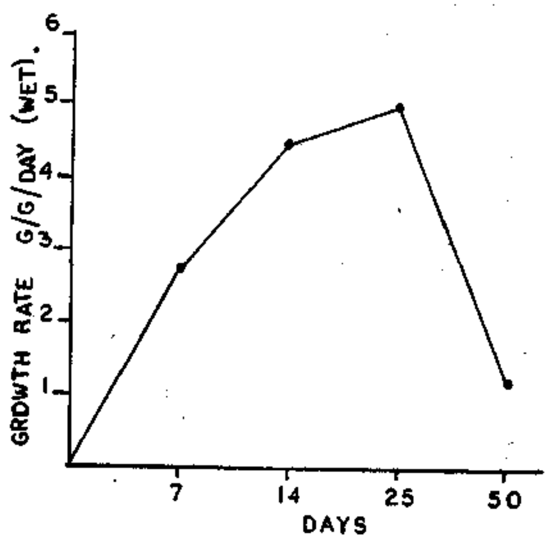

FIG. 1. Growth rate in biomass of *Hypnea musciformis* on culture rope (coir) at Krusadai Island.

four fold increase in biomass with a yield of 6.34 kg in 25 days was obtained. Subsequent to first harvest taken in September, the plants continued to grow till December 1979, but not to the level of harvest.

DISCUSSION

Humm and Kreuzer (1975) have shown the potentialities for cultivating *Hypnea musciformis* by recording doubling in weight in two days in the Caribbean Sea. Mshigeni (1976) has successfully cultivated *Hypnea cervicornis* starting from spores, to maturity in 3 months time. The faster growth rate of *Hypnea cervicornis* germlings was found to be advantageous over that of *Chondrus crispus*. Higher yields of 4.5 to 12 g/m^2/day of *Hypnea musciformis* were reported by Lapointe *et al.* (1976) in the outdoor mass culture in tanks by utilising a nutrient removal polyculture system. Haines

(1976) has also grown *Hypnea musciformis* in tanks containing surface seawater enriched with artificial fertilizer or domestic seawage and deep water effluent from clam mariculture system and recorded a 5 fold increase of growth in 40 days. Further potentialities for the use of *Hypnea* to remove the nutrients in polyculture systems known as recycling aquaculture system, has also been indicated by Michanek (1978). On the Indian Coast *Hypnea musciformis* propagates more by vegetative (organs) 'Tendrils' (Rama Rao, 1979). However, population arising from spores remains to be critically studied. Rama Rao (1970, 1972, 1977 a, b, 1979) has found that plants start growing in October and attain maturity in March.

The present study has given a basic technique for cultivating *Hypnea musciformis* in the lagoons by using vegetative fragments and was found to be effective in raising the crop in a short span of 25 days. This method has got an advantage over the spore culture technique. because of complete survival and fast growth of the 'seed' material. Further improvements will comprise in raising the crop yield and the number of harvests in a year.

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STUDIES ON THE FAUNA ASSOCIATED WITH THE CULTURED SEAWEED *GRACILARIA EDULIS*

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ABSTRACT

With a view to study the fauna associated with the cultured seaweed *Gracilaria edulis* in coastal waters of the Palk Bay and the Gulf of Mannar and to assess the damage, if any, caused by any of the organisms, samples of all animals associated with the cultured seaweeds were collected from the seaweed culture sites. Qualitative analysis of the samples indicated that the fauna is mainly composed of crabs, amphipods, polychaetes, isopods, copepods, gastropods, bivalves, holothurians and fishes. Quantitatively, crabs were found to be more numerous than all other groups, followed by amphipods and polychaetes.

Observations indicated damage to growing tips of the seaweed during April to August. This period coincides with the period when the direction of the wind changes from east-west to south-north direction. In order to ascertain whether any of the major organisms like fishes and crabs were grazing on the seaweed, fishes were captured by operating traps and cast nets in the vicinity of the culture frames. The crabs were hand picked. Analysis of the stomach contents of the fishes revealed that of the sixteen species of fishes encountered, only *Siganus javus* was found to feed voraciously on the seaweed. The crabs represented by *Thalamita crenata* and *T. integra* though not found to feed on the seaweed, could cause extensive damage to growing parts of the seaweed by merely clipping them with their chelipeds as they crawl about amongst the seaweeds. However, greater part of the damage to the cultured seaweed during the period appears to be caused by wind and wave action when the sea becomes rough.

INTRODUCTION

FAUNA associated with seaweeds have attracted the attention of many scientists from various parts of the world. Colman (1940) studied the fauna of the algae in the tidal zone from the English Channel. Wieser (1952) studied the phytal fauna from the English Channel and the Mediteranean and Chapman (1955) from the Azores. Dahl (1948) and Sloane *et al.* (1961) also contributed to this aspect of study from Swedish Coast and Lough Ine Rapids. In India, Sarma and Ganapathy (1972, 1975), Sarma (1974) and Joseph (1978 a, b, c) studied the fauna associated with the seaweeds. However, most of these observations were from the natural seaweed beds.

The Central Marine Fisheries Research Institute has been engaged in the cultivation of seaweeds for the past few years. Observations on the cultured seaweed *Gracilaria edulis* revealed the association of a number of groups of animals with the cultured seaweeds. Further, considerable damage to the growing tips was also noticed especially during the months April to August. Since detailed observations have so far not been available on the fauna associated with the cultured seaweed and the probable damage, if any, by various animals to the seaweed, the present study has been initiated. The results of this study are given in this paper.

Material and Methods

Periodic collection of all animals were made from the seaweed culture frames (made up of coir ropes) by removing them to the shore and picking up the animals found on the seaweeds. At times, portions of the frames with seaweed were washed in big tubs to separate the animals attached to the seaweeds. Later, they were preserved in 5% formalin for laboratory analysis. Some of the crabs belonging to the genus *Thalamita* were brought alive to the laboratory and kept in glass tubs containing seawater to observe whether they were feeding on the seaweeds supplied to them. Cast nets and fish traps were operated to capture the fishes that hover around the culture frames. Stomach contents of these fishes were analysed, for qualitative analysis of food items. All the above collections were made from four different culture sites in the Gulf of Mannar near the CMFRI jetty, Hare Island, Vedalai and Marakayarpatnam during the year 1979.

Observations

The analysis of samples of fauna collected from the cultured seaweed (*G. edulis*) indicated that amphipods, copepods, decapods, gastropods, holothurians, isopods, pelycypods and polychaetes are associated with the seaweeds.

Quantitatively, crabs (genera *Thalamita, Plagusia* and *Charybdis*) were found to be more numerous than all other groups followed by amphipods and polychaetes.

In order to ascertain whether the major predatory organisms like fishes and crabs were grazing on the seaweeds, the stomach contents of the fishes belonging to sixteen species collected from the culture sites were analysed. The details are given below.

Table 1. *Details of analysis of stomach contents of fishes and crabs captured from seaweed culture sites*

Species	No. of specimens examined	Size range (mm)	Stomach contents
Fishes			
Allanetta sp.	200	56—110	Amphipods, digested animal matter, copepods, partly digested crustacean appendages, isopods, partly digested plant matter.
Belone incisa	5	217—402	Bones and scales of fishes, Seagrass (*Diplanthera uninervis*).
Chaetodon sp.	5	98—102	Partly digested animal matter, *Gracilaria edulis*.
Ellochelon waigiensis	4	132—285	Seagrass sand particles, digested plant matter, copepods.
Epinephelus sp.	3	48—218	Partly digested animal matter.
Gerres sp.	1	109	Partly digested animal matter.
Gobius sp.	1	51	Crustaceans, fish scales. molluscs and amphipods.
Gymnothorax undulates	1	402	Empty.

Species	No. of specimens examined	Size range (mm)	Stomach contents
Hemirhampus sp.	2	142—148	Empty.
Leiognathus daura	76	75—102	Copepods, amphipods and other crustaceans.
Lethrinus sp.	8	131—255	Digested plant and animal matter.
Lutjanus sp.	6	42—177	Amphipods, fish scales, crustacean appendages.
Parapercis sp.	1	61	Algal matter.
Penaeus indicus	5	184—240	Partly digested plant and animal matter.
Plectorhyncus sp.	21	136—313	Partly digested animal matter.
Plotosus sp.	32	43—51	Copepods, decapods and amphipods.
Psamoperca waigiensis	4	120—156	Crabs and other crustaceans, partly digested plant matter seagrass.
Scarus ghobban	22	160—264	Pulpy matter.
Scatophagus argus	1	126	Empty.
Siganus canaliculates	11	129—172	*Gracilaria edulis* and partly digested plant matter.
Siganus javus	25	34—143	*Gracilaria edulis*, *D. uninervis*, algae (*Chaetomorpha* sp., *Lyngbia* sp., *Cladophora* sp., *Champia* sp.), Copepods.
Sphyraena sp.	4	63—71	Crustacean larvae.
Tetrodon sp.	10	39—73	Partly digested animal matter, molluscs, sand particles, seagrass, *G. edulis*.
Therapon puta	64	26—60	*D. uninervis*, Blue green algae (*Lyngbia* sp.), amphipods, decapods, pycnogonids, fish scale, copepods, gastropods and isopods.
Thrissa setirostris	35	43—101	Partly digested matter.
Upeneus sp.	1	56	*D. uninervis*, animal matter.
Crabs			
Thalamita crenata	33	32—48	*D. uninervis*, animal matter, sand particles.
Thalamita integra	639	6—49	*D. uninervis*, animal matter, sand particles, *G. edulis*.
Plagusia sp.	8	12—34	Seagrass and sand particles.
Charybdis sp.	14	49—76	Animal matter, sand particles, *Gracilaria edulis*.

Ellochelon vaigiensis

The size range was 165 mm to 285 mm. The stomachs were only half full in most of the fishes examined. The stomach contents included sea grass (*Diplanthera univervis*) and some microscopic algae, copepods and sand grains. No seaweeds were found.

Allanetta sp.

The size range was 56 to 110 mm. Stomachs were either empty or contained traces of semidigested food. The stomach contents included isopods, fish scales, copepods, crustacean appendages and partly digested animal matter. These fishes also have not been found to have fed on seaweeds, even though they were found in large numbers near the culture sites. Large number of fishes of this species were collected, but only 180 specimens were examined for stomach contents.

Therapon puta

The size range was 26 to 65 mm. Most of the fishes have fed well, their stomachs being three-fourths full. This species was also found in good numbers near the culture sites, but they were not found to have fed on the seaweed. The food items included mainly amphipods and copepods. Fish scales, gastropods, pycnogonids and decapods were also found. Blue green algae such as *Lyngbya* sp. and seagrass *Diplanthera uninervis* were found in very small quantities.

Upeneus sp.

The size of the fish examined was 56 mm. The stomach contents included small quantities of partly digested animal matter. Seagrass (*Diplanthera uninervis*) was also found.

Siganus javus

The size range was 34 to 143 mm. Most of the fishes have fed very actively and their stomachs were full or three-fourths full. Almost all the fish examined fed well on *G. edulis*, the seaweed forming almost three quarters of the food consumed. Some have exclusively fed on the seaweed. Eventhough these fishes have also been found to accept animal food (as evidenced by fishermen using prawn heads as baits in traps to capture these fishes), in natural conditions, they seem to prefer only plant food. Fishes collected near the culture sites also fed on other materials such as *Diplanthera uninervis*, *Champia parvula*, *Cladophora* sp. and *Chaetomorpha* sp. However, they seem to prefer *G. edulis*.

Siganus canaliculates

The size range was 129 to 172 mm. They have fed on *G. edulis* in considerable quantities. Of the 11 fishes examined all but two had their stomachs half full with this seaweed. Partly digested plant matter was also found in its stomach.

Leiognathus daura

The size range was 75 to 102 mm. They have fed upon copepods, amphipods and other crustacean. No seaweed or any other plant food was noticed in their stomach.

Scarus ghobban

The size range was from 160 to 264 mm. Pulpy matter was found in the stomachs of all the fishes examined.

Thrissa setirostris

The size range was 43 to 101 mm. Here also the stomachs contained only pulpy matter and no trace of seaweed was identified.

Other fishes

Other fishes that were studied occurred only in very limited numbers. Of these, the stomachs of *Gymnothorax undulates* and *Scatophagus argus* were found empty. *Epinephelus* sp. and *Gerres* sp. had partly digested animal matter in their food. Algal matter was found in traces in *Parapercis* sp., *Psamoperca waigiensis* preyed upon crabs and other crustaceans and their stomachs were full. Seagrass (*D. uninervis*) was also found in their stomach. The stomach contents of *Gobius* sp. included crustaceans, crustacean appendages, gastropods and fish scales. *Belone incisa* had bones and scales of fishes and seagrass (*D. uninervis*) in its stomach. *Plotosus* sp. mainly fed upon copepods, amphipods and decapods. *Lutjanus* sp. preyed upon amphipods and other crustaceans. Fish scales were also found in their stomachs. *Tetrodon* sp. preyed upon molluscs and seagrass. Large quantities of sand were also found in their stomachs. In one specimen, bits of *G. edulis* were found. *Chaetodon* sp. had partly digested animal matter and had negligible amount of *G. edulis* in one of the specimens. The stomachs of *Hemirhamphus* sp. and *Chaetodon* sp. were found empty. *Lethrinus* sp. and *Penaeus indicus* had partly digested plant and animal matter in their stomachs. *Sphyraena* sp. had crustacean larvae in their stomach.

Crabs

Thalamita crenata and *T. integra* had seagrass and animal matter along with sand particles. In one of the specimens of *T. integra* bits of *G. edulis* were found. *plagusia* sp. had seagrass and sand particles. *Charybdis* sp. had partly digested plant and animal matter along with sand. Of the fourteen specimens examined, *G. edulis* formed half of the stomach content in one and only traces in another.

Discussion

As seen from the above results, of twenty-six species of fishes that were captured in the vicinity of seaweed culture sites, only *Siganus javus* and *S. canaliculates* were found to have fed on *G. edulis*. Some of the fishes like *Therapon puta* and *Leiognathus daura* collected in good numbers near the culture sites were found to be feeding mainly on animal food. Fishes belonging to the species *Allanetta* were found in large numbers around the culture frames, but they have not been found to feed on *G. edulis*. It is possible that some of the fishes might have got their algal food from the seaweed (*G. edulis*) on which they are epiphytic. Animals that were found in the stomach contents of fishes collected at the culture sites were also found associated with the seaweeds. Therefore, it is evident that these fishes and crabs and other organisms congregate around the seaweed for food or shelter or both, but not to prey directly on the seaweed, except in the case of fishes mentioned above. Crabs have been found to feed on seagrass. Of all the species, only *Siganus javus* have fed voraciously on the cultured seaweeds and *S. canaliculates* have fed considerably. But the abundance of this species captured near the culture sites was not so high to believe that the damage to the growing tips could be entirely due to grazing by this fish. Occurrence of very small bits of *G. edulis* in the gut contents of one specimen each of *Tetrodon* sp. and of one crab *T. integra* could be accidental. Two specimens of the crabs *Charybdis* caught in traps had *Gracilaria edulis* in their stomachs. The bait used in the traps was the same seaweed.

Joseph (1978 a) observed that feeding by algivores results in partial or total destruction of algal fronds. He (1978 b) also observed that the food habits affect the distribution of algae. According to him *G. edulis* is one of the algae preferred by the gastropods as food. The gastropods mentioned by him include *Pyrene versicolor*, *Aplysia benedicti* and *A. leneolata*, the bivalve *Modiolus striatus* and the polychaetes *Polyophthalamus pictus* *Pseudonereis anomala*, *Streblosoma persica* *Syllis* (*Typosyllis*) *krochnii*, *S. prolifera* and *Thelepus plagiostema* which, according to him, occur in fairly large numbers.

Closer observations in the culture sites indicated that damage to the growing tips can also be caused by the crabs by merely clipping them with their chelipeds as they crawl about amongst the seaweeds. Crabs that were brought to the laboratory alive and observed in glass troughs with seaweed suspended from above were also found to cut the seaweed into bits, confirming what was observed in the field. But in the other months, when crabs were found to be associated with well grown seaweed, no damage was found. However, the amount of damage caused to the growing tips of the seaweeds during the reported period of April to August is so enormous that grazing by the fish *S. javus* and clipping by the crabs could not account for the loss completely. During this period, the direction of wind changes from east-west to south-north direction, with the result that the sea becomes very rough with strong waves and heavy churning of coastal waters. These conditions are not only not congenial for growth of seaweed, but break off the twigs and also cover them with mud and silt which smother the weed completely. Hence, it is possible that these factors also contribute to the damage to the cultured seaweed during this period.

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EFFECTS OF ENVIRONMENTAL FACTORS ON THE SHEDDING OF TETRASPORES OF SOME GIGARTINALES (RHODOPHYTA)

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ABSTRACT

Studies on factors influencing liberation, settlement and germination of spores are needed for the cultivation of economically useful red algae on the Indian shores. In an autecological study carried out on some agar-yielding red algae (Gigartinales) of Visakhapatnam Coast, detailed information was gathered on the effects of environmental factors such as desiccation, salinity, temperature and intensity, duration and quality of light on the shedding of tetraspores of *Gracilaria corticata*, *Gracilaria textorii*, *Gracilariopsis sjoestedtii* and *Hypnea valentiae*. Spore output decreased with increase in the duration of exposure of the fronds to air and maximum output was obtained under submerged conditions. Tetraspore output varied in different salinities ranging from 10 to 60 ‰ and the optimum range observed for maximum shedding of spores was 20 to 30 ‰ in *Gracilaria textorii*, *Gracilariopsis sjoestedtii* and *Hypnea valentiae*. There was no spore discharge at temperatures below 15°C and above 35°C in the three algae tested. In experiments conducted at different light intensities and light and dark cycles, peak output was found in darkness or under short day conditions. Spore output was found to be higher in yellow light than in other coloured lights. The optimum limits obtained in the laboratory experiments were compared with the environmental conditions existing in the intertidal region of the Visakhapatnam Coast.

INTRODUCTION

STUDIES on environmental factors influencing sporulation in red algae of Indian shores are very few (Sreenivasa Rao, 1971 ; Umamaheswara Rao, 1974, 1976). While working on the autecology of certain members of Gigartinales of Visakhapatnam Coast, experiments were conducted under laboratory conditions for a proper understanding of the importance of desiccation, salinity, light and temperature or spore shedding and for assessing the optimum conditions for the release of maximum quantity of spores in some economically useful members of Gigartinales growing along the Visakhapatnam Coast. Results obtained on *Gracilaria corticata* J. Agardh, *Gracilaria textorii* (Sur.) J. Agardh, *Gracilariopsis sjoestedtii* (Kylin) Dawson and *Hypnea valentiae* (Turner) Montagne are presented in this paper.

We wish to express our sincere thanks to Prof. Keto E. Mshigeni, University of Dar-Es-Salaam, Tanzania for identifying *Hypnea* species of the Visakhapatnam Coast. One of us (G. S. R.) acknowledges the financial help received from the C.S.I.R. while carrying out this work.

MATERIAL AND METHODS

Spore shedding experiments were conducted using tetrasporic thalli of *Gracilaria corticata*, *Gracilaria textorii*, *Gracilariopsis sjoestedtii* and *Hypnea valentiae*. Materials collected during low tide were brought to the laboratory (in seawater) and small bits of fertile fronds of the same age group with well developed sporangia were selected for all the experiments. These fronds were treated with 1% Streptomycin solution, washed several times with sterile seawater and placed in petridishes (8 cm dia.) filled with sterile seawater of about 30 ml. In all these experiments on spore shedding 3 or 4 fronds were used in each petridish.

To study the effect of desiccation, the fronds selected were blotted with cloth to remove the external moisture and exposed to air in the laboratory (at 30 ± 2°C and 60-67% R.H.) and in the sun (at 34 ± 2°C and 58-63% R.H.) during day time at 10 a.m. At 15 minutes intervals the fronds thus exposed to air were transferred to petridishes containing seawater for estimating the spore output. Experiments for the effect of salinity were conducted at different salinities ranging from 10-70‰, following the method given earlier (Subbarangaiah *et al.*, 1975). Experiments on the effect of light intensity were conducted at 0, 750 ± 50, 1500 and 2000 Lux. For effect of photoperiod on spore output experiments were carried out (at 1,500 lux) under $0+\overline{24}$, $4+\overline{20}$, $8+\overline{16}$, $12+\overline{12}$, $16+\overline{8}$, $20+\overline{4}$ and $24+\overline{0}$ light and dark regimes, using separate light and dark chambers. For studying the effect of different wavelengths of light, the petridishes were covered with coloured cellophane papers and exposed to a light intensity of 750 ± 50 lux. The influence of 8 different temperatures (from −6°C to 40°C) on spore shedding was studied by keeping the petridishes for 24 hrs in a temperature controlled dark incubator or deep freezer. Experiments on desiccation and salinity were conducted at room temperature (31 ± 2°C) keeping the petridishes near a light source of 1,500 lux from 10 a.m. to 6 p.m. Ten experiments were conducted with *Gracilaria corticata* and *Hypnea valentiae* and five experiments with *Gracilaria textorii* and *Gracilariopsis sjoestedtii* for each factor, commencing all from 6 p.m. in the evening except disiccation experiments which were conducted in bright sunlight. Certain experiments with *Gracilariopsis sjoestedtii* could not be conducted due to lack of sufficient material. The spores liberated were counted after 24 hrs, by preparing spore suspension of a known volume. Details of the method followed for counting the spores were given in another communication (Umamaheswara Rao, 1978). From the fresh weight of the tetrasporic fronds determined at the end of the experiments, the spore output/gm. Fr. Wt./day was estimated.

Observations

Results obtained on the effects of environmental factors on spore shedding in *Gracilaria corticata*, *Gracilaria textorii*, *Gracilariopsis sjoestedtii* and *Hypnea valentiae* are plotted in Fig. 1-6. Fig. 1 shows the variations in the spore output observed in control (0 hrs of exposure) and in different periods of exposure to air in the laboratory and in the sun. Maximum spore output was found in the four algae in fronds submerged for 24 hrs period (control) and with increase in the duration of drying of fronds the spore output decreased. (Fig. 1). In *Gracilaria corticata*, *Gracilaria textorii*, spore output declined rapidly from 15 to 45 minutes drying at room temperature. Gradual reduction in spore output was observed in fronds of *Gracilariopsis sjoestedtii* exposed to air at room temperature. Marked reduction in spore shedding was seen in the fronds of *Hypnea valentiae* exposed even for 15 minutes, indicating that this alga is more sensitive and cannot tolerate desiccation even for short period. In the experiments conducted in the sun, the spore production was less than in the shade at room temperature (Fig. 1) and among the four algae conspicuous changes were seen in *Gracilaria corticata*, *Gracilariopsis sjoestedtii* and *Hypnea valentiae*. Under these conditions of high temperature and low humidity there was no spore discharge after 1 hour (Fig. 1) in all the red algae tested.

Effects of salinity on spore shedding in *Gracilaria textorii*, *Gracilariopsis sjoestedtii* and *Hypnea valentiae* are shown in Fig. 2. Spore liberation was seen in *Gracilaria textorii* at salinities ranging from 20—50‰ and in *Gracilariopsis sjoestedtii* from 20—60‰. In *Hypnea valentiae* spore shedding was seen in salinities ranging from 10—40‰. Within

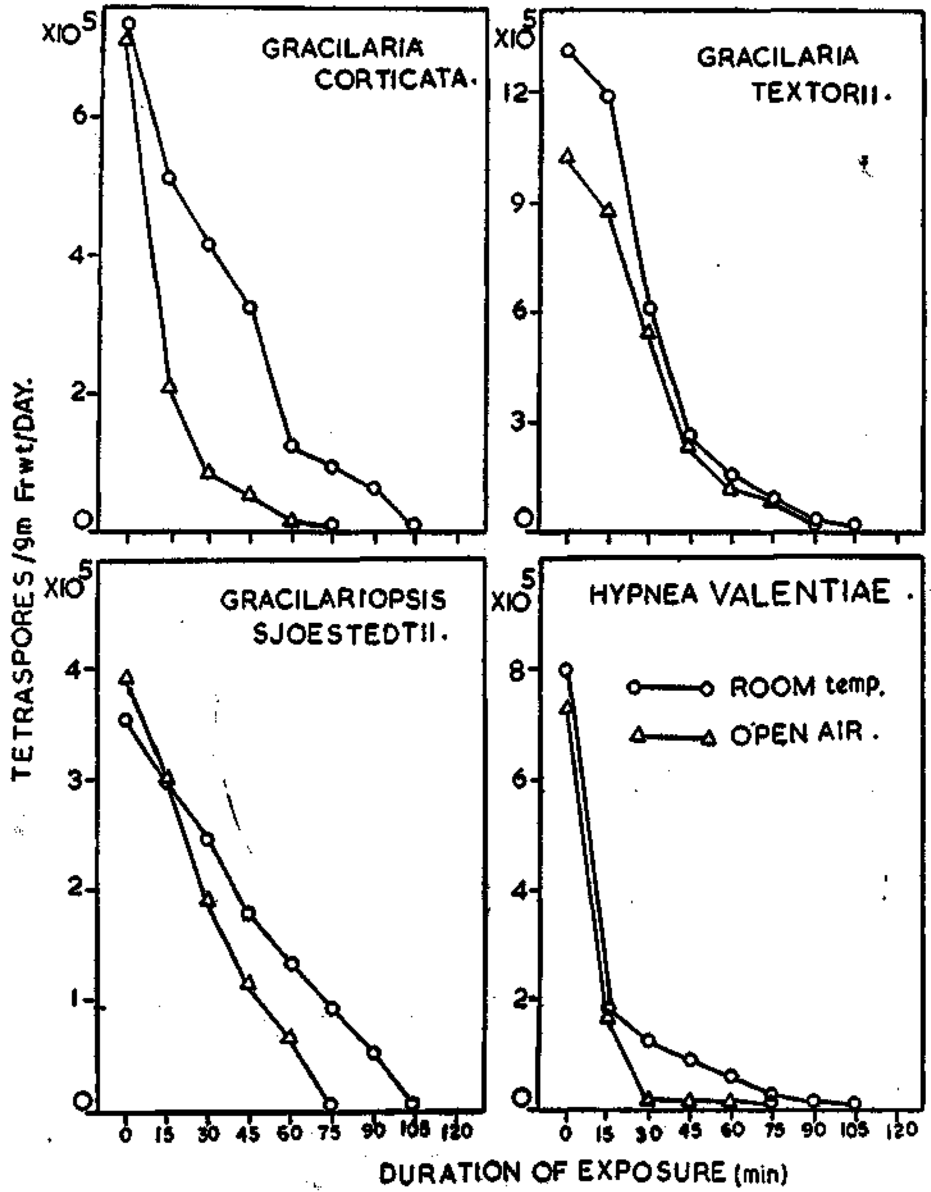

FIG. 1. Effect of exposure to air on the tetraspore output of *Gracilaria corticata*, *Gracilaria textorii*, *Gracilariopsis sjoestedtii* and *Hypnea valentiae*.

these salinity ranges the spore output varied markedly in the three Gigartinale members and maximum shedding was seen in *Gracilaria textorii* and *Gracilariopsis sjoestedtii* at 30‰. Dilute seawater appears to be favourable for the liberation of spores in *Hypnea valentiae* since peak shedding was observed at 20‰. The quantity of spores liberated in this alga at 30‰ salinity was also high (Fig. 2).

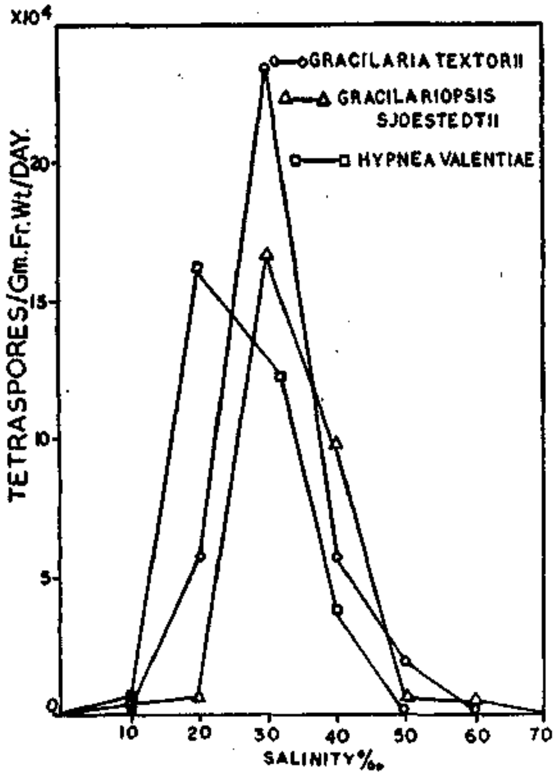

FIG. 2. Effect of salinity on the tetraspore output of *Gracilaria textorii*, *Gracilariopsis sjoestedtii* and *Hypnea valentiae*.

and the spore output decreased gradually in these three algae, with increase in light intensity from 750±50 to 2000 lux. In *Hypnea valentiae* spore production was less in dark and maximum shedding was seen at 750∓50 lux (Fig. 3). At 1500 and 2000 lux the spore output decreased as observed in the other members of the Gigartinales. Effects of light

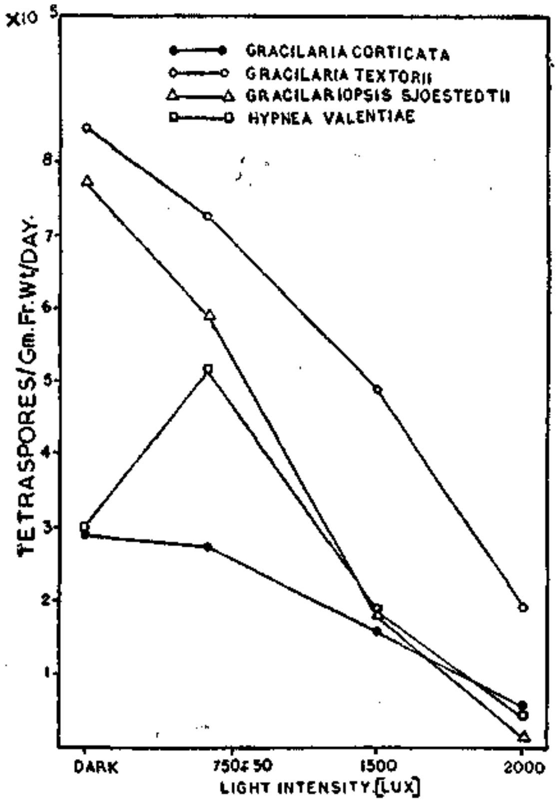

FIG. 3. Effects of light intensity on the tetraspore output of *Gracilaria corticata*, *Gracilaria textorii*, *Gracilariopsis sjoestedtii and Hypnea valentiae*.

Spore output values obtained in darkness and at 3 different light intensities from 750∓50 to 2000 lux are shown in Fig. 3. In *Gracilaria corticata*, *Gracilaria textorii* and *Gracilariopsis sjoestedtii* peak spore output was observed in complete darkness. The values obtained at 750∓50 lux were less than those obtained at 0 light intensity, especially in *Gracilaria corticata*

period or day length are shown in Fig. 4. As observed in the light intensity experiments, maximum shedding of spores was found in complete darkness in *Gracilaria corticata*, *Gracilaria textorii*, *Gracilariopsis sjoestedtii* and also in *Hypnea valentiae* and the spore output declined with increase in the duration of the photoperiod. The values obtained at

4+$\overline{20}$ LD cycle were higher than in the other light and dark cycles (Fig. 4). After 12+$\overline{12}$ LD cycle the changes in the spore output were not conspicuous and lowest values were obtained in 24 hrs photoperiod or continuous illumination. In *Hypnea valentiae* also decreasing trend was seen at 4+$\overline{20}$ LD cycle since these experiments were conducted at 1500 lux light intensity where the spore output was not high (Fig. 3). Data obtained in different wavelengths of light are presented in Fig. 5. In these preliminary experiments the quality of light influenced spore shedding. In *Gracilaria corticata, Gracilaria textorii* and *Hypnea valentiae* maximum shedding was observed in yellow light. The values obtained in yellow light were higher than those obtained in control experiments *i.e.* in normal day light (Fig. 5). In the blue, green and red lights the spore shedding was less when compared with the control.

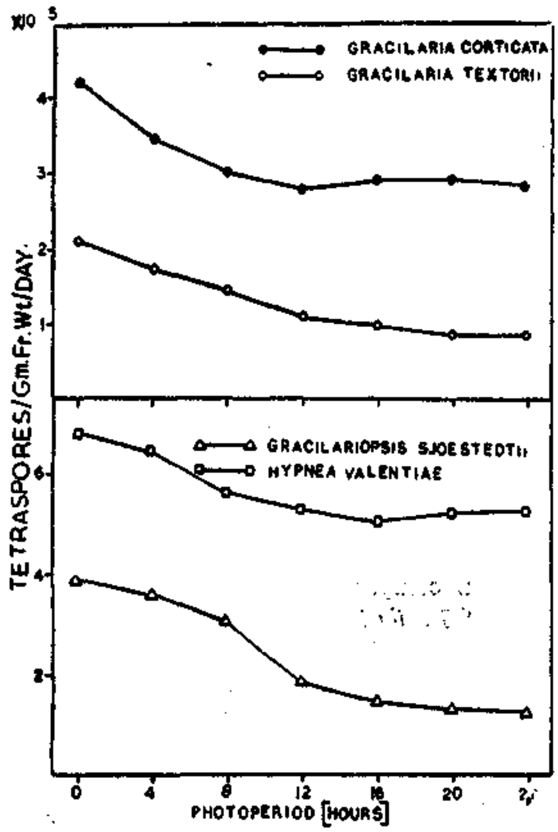

Fig. 4. Effect of photoperiod or daylength on the tetraspore output of *Gracilaria corticata, Gracilaria textorii, Gracilariopsis sjoetsedtii* and *Hypnea valentiae*.

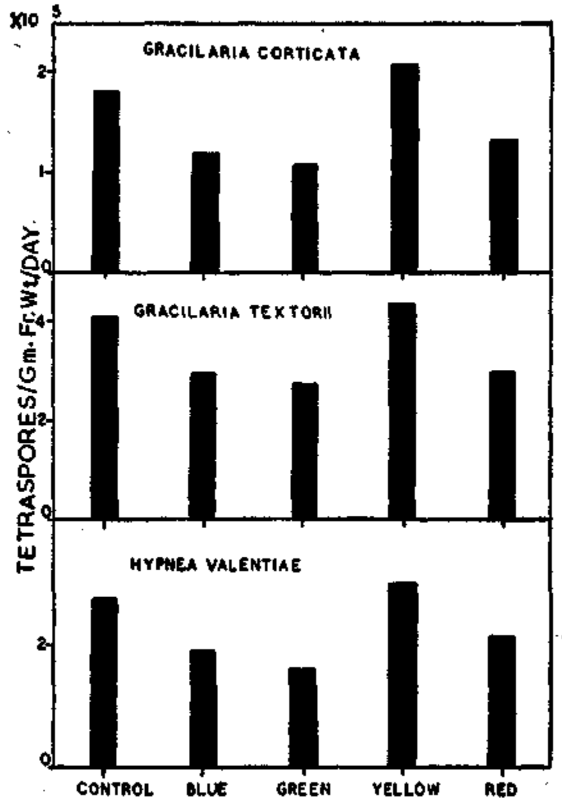

Fig. 5. Effect of wavelengths of light on the tetraspore output of *Gracilaria corticata, Gracilaria textorii* and *Hypnea valentiae*.

Variations observed in the spore output of *Gracilaria corticata, Gracilaria textorii* and *Hypnea valentiae* in relation to different temperatures ranging from 0 to 40°C are shown in Fig. 6. Spore liberation was not seen in these three algae at —6°C, 10°C, 40°C. In the other five temperatures ranging from 15°-35°C spore output varied markedly. As shown in Fig. 6 from 15°C the spore output increased and peak shedding was obtained at 30°C in the three members of Gigartinales studied. The spore output decreased rapidly after 30°C and lowest values were obtained in *Gracilaria corticata* and *Gracilaria textorii* at 35°C. But in *Hypnea valentiae* there was no shedding

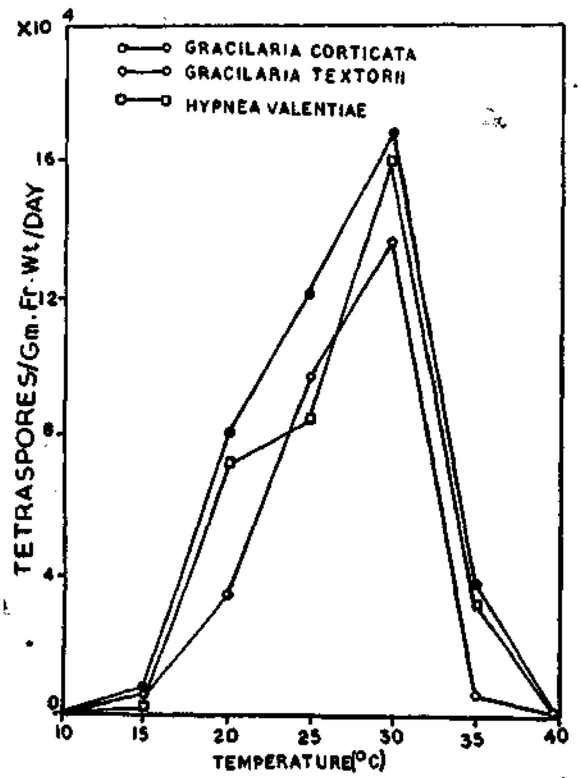

FIG. 6. Effect of temperature on the tetraspore output of *Gracilaria corticata, Gracilaria textorii* and *Hypnea valentiae.*

of spores even at 35°C. These observations suggest that the temperatures between 25°C-30°C appear to be optimum for the discharge of maximum number of spores in *Gracilaria corticata, Gracilaria textorii* and *Hypnea valentiae*.

DISCUSSION

From the foregoing account it is clear that marked variations occur in spore shedding in relation to changes in the environmental factors. Though desiccation of fronds enhanced spore production in *Gloiopeltis* species (Matsui, 1969), decrease in spore output was seen in the present study (Fig. 1), indicating that the emergence of fronds during low tides adversely affects spore liberation. These observations agree with the findings of Umamaheswara Rao (1976) on *Gracilaria corticata* and Katada (1955) and Sreenivasa Rao (1971) on other red algae like (*Gelidium* and *Gelidiella*. Unlike in the observations of Matsui (1969), significant variations were found in *Gracilaria textorii, Gracilariopsis sjoestedtii* and *Hypnea valentiae* in different salinities with maximum discharge of spores between 20-30‰. In *Gracilaria corticata* peak shedding was seen at 40‰ and the spore output was also high at 30‰ (Subbarangaiah *et al.*, 1975).

High light intensities and long day conditions enhanced spore liberation in red algae like *Acrochaetium endophyticum* (White and Boney, 1969). On the other hand in the Gigartinales studied (Fig. 4), peak discharge of spores was found in complete darkness in *Gracilaria corticata, Gracilaria textorii* and *Gracilariopsis sjoestedtii*; at 750 ∓ 50 lux in *Hypnea valentiae*. There appear to be no earlier reports showing the influence of yellow light on spore shedding as observed in present study. However, in studies made by Boney and Corner (1962, 1963) on *Plumaria elegans* and *Antithamnion plumula* and Kling (1974) on *Gracilaria verrucosa*, yellow light promoted the growth and development of germlings of these algae. More detailed studies are needed on the effects of light energy and its quality on spore shedding. Spore emission was affected considerably at different temperatures in the members of Gigartinales studied (Fig. 6). The temperature tolerance limits and optimum range of 25-30°C observed for the algae of the Visakhapatnam Coast were higher than the ranges reported for red algae growing in other geographical areas

(Suto, 1950; Kurogi and Akiyama, 1966; Matsui, 1969).

These findings on different factors clearly indicate that submerged conditions of the plants, complete darkness and short days, seawater of 20 to 30‰ (or upto 40‰) salinity and 25-30°C temperature are favourable for spore shedding in *Gracilaria corticata, Gracilaria textorii, Gracilariopsis sjoestedtii* and *Hypnea valentiae*. The optimum ranges of salinity and temperature observed in the laboratory experiments coincide with the annual ranges of salinity (21-35‰) and temperature (24-29°C) recorded for the inshore waters of the Visakhapatnam Coast (Ganapathy and Satyanarayana Rao, 1962; Umamaheswara Rao and Sreeramulu, 1964).

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SEAWEED CULTURE — ITS FEASIBILITY AND INDUSTRIAL UTILIZATION

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ABSTRACT

Culture of seaweeds is practiced since ages in countries such as Japan, China and Korea. Seaweed cultivation is an industry in Japan as a part-time avocation for land farmers and fishermen. The seaweeds cultured mainly in these countries are *Porphyra*, *Undaria*, *Laminaria*, *Enteromorpha* and *Monostroma*. In India seaweed culture is yet to develop on commercial lines. While the demand for these seaweeds is for food purposes in foreign countries, their demand in India is for the extraction of two phytochemicals namely agar-agar and algin. In recent years many factories manufacturing these chemicals have come up in India as a consequence of which the demand for the agarophytes and alginophytes has gone up. In order to maintain a continuous supply of this raw material to the industry, methods to augment the supplies through culture practices have to be developed.

In recent years the Central Marine Fisheries Research Institute has been engaged in the cultivation of several economically important seaweeds such as *Sargassum wightii*, *Turbinaria* spp., *Gracilaria edulis*, *G. corticata* and *Gelidiella acerosa* which indicated great scope for cultivation. The production rate has been found to be 4.4 kg/m^2 in the case of *G. edulis* and 3 kg/m^2 in the case of *G. acerosa* in about 80 days for 0.30 kg and 1 kg of seed material introduced respectively. In the case of alginophytes the growth was not encouraging. These culture experiments were conducted by introducing small fragments of the seaweed into the twists of the coir ropes fabricated in the form of a 5×2 m net and tied to fixed poles in inshore waters. In the case of *G. acerosa*, the substratum along with the plant fragments was tied to the ropes.

The agarophytes thus grown can be processed further for extraction of agar-agar. The extraction could be done by a simple cottage industry method not involving any costly equipment. In the case of *Gelidiella* agar, freezing and thawing are required to remove the insoluble chemicals. A total of 90 tonnes of *G. edulis* can be obtained from 3 harvests in a year from a hectare area.

INTRODUCTION

CULTURE of seaweeds is practiced since ancient days in countries such as Japan, China and Korea. In Japan, cultivation of marine algae especially *Porphyra* has been in vogue on large scale which probably originated in 17th century. Seaweed industry is an industry in Japan mostly as a part-time avocation for land farmers and fishermen. Species of *Enteromorpha*, *Monostroma*, *Laminaria* and *Undaria pinnatifida* are intensively cultivated in Japan. *Porphyra* is cultivated in Korea also. Raft culture of *Laminaria japonica* using wooden frames has yielded very good results in China though the sea floor culture is still prevalent in Japan and Korea.

In India seaweed culture is yet to develop on commercial lines. The Central Marine Fisheries Research Institute has been working to evolve methods of culturing commercially important seaweeds such as the agar yielding *Gelidiella acerosa*, species of *Gracilaria* and the algin yielding *Sargassum* spp, and *Turbinaria* spp. There is heavy demand for the two phycocolloids agar-agar and algin extracted from these seaweeds since they are used in textiles, ice-cream, confectionary, film, rubber, liquor, varnish and paint industries. Many factories manufacturing these phytochemicals have come up in recent years and hence the demand for raw material also increased.

The standing crop of *Gelidiella acerosa* and *Gracilaria edulis* in the natural environment is declining every year due to indiscriminate harvesting by fishermen throughout the year without observing any periodicity and removal of plants alongwith their holdfast. Over-exploitation of these algae from their natural beds leads to decline in population in the subsequent year while the demand for these seaweeds increases every year. In order to meet this ever increasing demand by the agar industries, their supply is to be augmented by adopting culture practices.

Culture

The necessity for and the principles and problems connected with seaweed culture have been discussed by Krishnamurty (1965). Edwyn Isaac (1956) has shown that fragments of *Gracilaria confervoides* can propogate vegetatively.

Preliminary culture experiments carried out in India with some of the economically important seaweeds such as *Sargassum cinctum*, *S. plagiophyllum*, *Gracilaria edulis* and *Gelidiella acerosa* (Thivy, 1964 ; Raju and Thomas, 1971 ; Umamaheswara Rao, 1974 ; Chennubhotla, 1976 ; Chennubhotla *et al.*, 1977) indicated that there is great scope for the cultivation of these species. These culture experiments were conducted by introducing fragments of the seaweed (along with holdfast in the case of alginophytes) into the twists of the coir ropes which in some cases were fabricated in the form of nets of different sizes woven round supporting side frames of wooden poles or G.I. pipes. These ropes and nets were tied to wooden poles fixed in the coastal waters. In the case of experiments with *Gelidiella acerosa* a portion of the plant along with substratum was tied to the coir ropes.

In the cultivation of *G. edulis* carried out near Mandapam, it was found that a total of three harvests could be made within one year and the annual yield has been calculated as 3.5 kg of fresh seaweed per metre of coir rope (Raju and Thomas, 1971). Umamaheswara Rao (1974) reported an yield of 4.4 kg of fresh seaweed of *Gracilaria edulis* per square metre of coir net within 80 days for an initial seed material of 0.3 kg. Chennubhotla (1976) reported an yield of 2 kg of fresh *G. edulis* per square metre of coir net within 45 days for an initial seed material of 0.35 kg. *G. edulis* cultured in Athankarai Estuary showed slight bleaching as compared to that cultured in inshore waters. Lower salinity near the estuary mouth during monsoon enhanced the development of the half dead fragments of *G. edulis* and fresh growth started with new shoots springing up. Low salinities giving encouraging results of the growth of seaweeds has been reported by Krishnamurty (1954) and Kurogi (1963). *Gelidiella acerosa* has a slow growth and yielded a harvest of 3 kg from an initial seed material of 1 kg after 77 days growth (Chennubhotla *et al.*, 1977) In *Sargassum plagiophyllum*, Raju and Venugopal (1971) observed a period of 9-10 months for it to settle on artificial substrata such as concrete cylinders after which rapid growth was observed and near mature plants were seen within nine months. Thivy (1964) reported a growth of 37-52 cm for an initial height of 10 cm in *Sargassum cinctum* within 40 days. The trial experiments with *Gracilaria corticata*, *Sargassum wightii* and *Turbinaria decurrens* have shown that these species have got the capacity to regenerate from the vegetative fragments.

Recently, cultivation of *G. edulis* near Central Marine Fisheries Research Institute Jetty at

Mandapam Camp was carried out in 0.2 hectare area using 5×2 m size coir nets without wooden or G.I. pipe supporting frames. This has brought down the cost of production as the cost of G.I. pipe or wooden frame was eliminated. In these experiments the crop was harvested after 60 days without waiting for 80 days as in the earlier occasions as the chances of the fully grown seaweed being washed away after breaking due to wave action or winds and grazing by fish could be avoided. An average yield of 30 kg for an initial seed material of 10 kg/net was obtained. It was found that there was no appreciable difference in the yield of agar-agar between the 60 days grown and 80 days grown plants except for the gel strength (Thomas and Krishnamurty, 1976), but the gel strength could be improved according to the requirements by blending with other agarophytes such as *Gelidiella acerosa* having higher gel strength.

In this paper the details regarding the cultivation of *G. edulis* based on the above result, the possibilities of extraction of agar-agar from the harvested seaweed and the economics of culture operations in relation to agar extraction are discussed. Full information on the cultivation of other economically important seaweeds is not yet available.

An alternate method of culturing seaweeds is to collect sporophytic plants, liberate the spores in the laboratory, rear them and allow to settle and germinate on suitable substrata like coral stones, transfer them to the sea for growing in to adult plants. But the methods by using fragments is easier and the growth is quicker.

Feasibility and Industrial Utilization

In one hectare area, 1,000 coir nets of 5×2 m size could be introduced with *G. edulis*. At the rate of 30 kg per net, 30 tonnes of fresh *G. edulis* could be harvested after 60 days. Three harvests could be made in a year and the total harvest would be 90 tonnes of fresh weed. The dry weight of this weed will be 1/8th of the fresh weight. The yield of agar from the dry weed will be 15% by weight. Thus 1.687 tonnes of agar-agar could be extracted from the harvested material from one hectare in a year which may fetch a price of Rs. 100 per kg.

The extraction of agar from *Gracilaria edulis* could be done by a simple cottage industry method evolved by the Central Marine Fisheries Research Institute (Thivy, 1960) not involving any costly set up. The process consists of cleaning the dry weed by repeated washings in fresh water and sun bleaching. The clean dried weed thus obtained is chopped to small bits, ground in grinder and soaked in soft water for 24 hours. Soaked seaweed is next ground into a paste which is leached in water for 24 hours. This process will leach out all water soluble minerals. This is dried again and boiled in soft water at 90°C for about one hour. The ratio of seaweed meal to soft water is 1 gm : 30 ml. The extraction of agar is good in acidic conditions and hence a lime fruit may be squeezed into the boiling water. During extraction the material is stirred well, after extraction is completed the vessel is kept insulated so that the sol will remain liquid for some hours during which time the suspended impurities will settle down ; when the sol has set into a firm gel the clear gel is removed leaving the sediment behind ; the gel is melted and poured into trays so that it can be cut into strips later. The gel strips are dried on plastic net supported on a galvanized wire cage ; it is best to dry the gel indoors to prevent dust settling on it ; drying being effected under an electric fan or in hot air at 60°C. After drying, the agar strips are collected and if necessary powdered by grinding in coffee grinder.

In the case of extraction of agar from *Gelidiella acerosa*, freezing technique is employed to retain the cold water soluble fraction of agar and since it is not possible to remove the impurities from the weed effectively as in the case of *Gracilaria edulis*.

Conclusion

Profit margin is assured only if the extraction of agar-agar is undertaken by the farmer himself. If the harvested fresh plants or dried plants are sold, it will be uneconomical since the cost of production per kg of fresh plants comes to Rs. 1.50 whereas the naturally collected pure material costs Rs. 0.25 per kg only. The farmer and his family members or some families jointly have to undertake on co-operative basis the cultivation of seaweeds and extract agar-agar by cottage industry method to bring down the cost of production. At present the cost of cultivated seaweed may be higher than that collected from natural environment, but in future when the denudation of natural vegetation occurs and the cost of collected material shoots up then the cost of both may become equal. Methods for cultivating seaweeds are developed and recommended to augment the supplies to the industries at present and to serve the future shortage in supply.

The coastal population have to attempt for cultivating seaweeds in a co-operative manner and extract the agar-agar in their villages. If soft water is not available in the village, demineralisation plants could be set up for getting soft water from the available hard water. The soft water could be obtained by installing solar stills or tube wells. At present, the seaweed industries are taking the major profit by paying lesser rate to the raw materials. If extraction of agar and algin is undertaken by the fishermen — farmers themselves, this profit also accrues to them.

The cultivation of seaweeds is beset with problems such as grazing by fish in the sea and hence sometimes the yield in the crop and thereby production may come down from the expected level.

In order to enable the fishermen or landless labour to undertake the seaweed cultivation the Government is offering certain credit facilities with subsidies under the programmes such as I.R.D.P., D.P.A.P., etc., which will be of immense use to them. These schemes are to be utilized for raising loans for strarting the seaweed culture.

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FEASIBILITY OF SEAWEED CULTURE IN NORTHEAST AREAS OF BRAZIL I. INTEGRATED CULTURE OF *HYPNEA MUSCIFORMIS* WULFEN AND LAMOUROUX, *GRACILARIA VERRUCOSA* (HUDSON) PAPENFUSS AND *CRASSOSTREA MANGROVE*

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Abstract

In 1977 the Department of Oceanography and Limnology of U.F.R.N., Natal started an integrated programme to study the feasibility of combined culture of seaweed and oyster in the brackishwater fish ponds near Potengi Estuary. The ponds were supplied with a fresh flow of tidal water during every high tide. The species selected for combined farming are the agarophytes *Hypnea musciformis* and *Gracilaria verrucosa* and the oyster *Crassostrea mangrove*. Data on productivity pattern, physico-chemical and biological characteristics of the study area together with economical feasibility of the culture operations are presented in the paper. These seaweeds as well as the oyster are found to grow well in the brackishwater fish ponds. Following the success achieved in this experiment, an intensive integrated culture of seaweed and oyster in the brackishwater fish ponds are now fastly developing on a commercial scale in North-east Brazil

Introduction

While suggesting the positive increase in growth rate of agarophytic algae, Oswald *et al.* (1975) put forth an idea that cultivation should be of mutual benefit for nutrients (particularly ammonia) liberating animals during their active growth which incidentally serves as a nutrient to the alga thereby opening new vistas algal cultivation. In our present study here, we have successfully obtained an integrated (joint cultivation of economically viable plants and animals in an aquatic system) cultivation of *Crassostrea mangrove* Guilding an agarophytic marine algae. We had also taken care to minimise the growth of epiphytic diatoms which tend to inhibit the growth of marine algae and at the same time maintaining an adequate nutrient supply for exponential growth of *Gracilaria verrucosa* and *Hypnea musciformis*. The initial success of integrated cultivation has prompted us to study intensively in view of the fact that North-east Brazil's economic benefits from biological research is developing fast. Our preliminary study includes a successful trial of cultivating agarophytic marine algae, such as *G. verrucosa* and *H. musciformis* with that of molluscs utilizing fallow ponds, used previously for growing *Mugil* spp.

The experiments were carried out for one year (1.1.1977 to 31-12-1977). The basic materials were collected from the intertidal region of beaches and transferred to saltwater ponds. The oyster, *Crassostrea rhizophora* present abundantly and perenially in the estuary of Potengi River had also been transfer-

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red together with marine algae. The cultivation had been successfully carried in the fallow ponds belonging to our department, situated on the margins of Potengi Estuary, which is roughly 5 km away from the coast.

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Materials and Methods

Pond

It is a typical fishpond of North-east Brazil, has an area of 0.1 ha with water holding capacity of minimum of 80 cm and a maximum of 120 cm. The high tides bring water to the pond and circulation is perfectly maintained.

The intertidal marine algae were collected and safely transferred to ponds.

Gracilaria verrucosa were collected from Maracajau Beach, very near to Tereza Panca light house. It is more or less a shallow area situated at a latitude 5° 25'S and longitude 35° 19'W. The collections were made from a depth of 4.5 m and exactly at 06.00 hours. The physico-chemical characteristics recorded at the time of collection were: salinity 35‰, dissolved oxygen 3.5 ml/l, temperature 27°C and transparency 4 m (Secchi disc). The *Gracilaria* spp weighing approximately 64 kg were collected in a plastic sac with sufficient seawater and a few cube of ice and transferred safely to ponds for cultivation.

Hypnea musciformis has been collected from Buzios Beach, situated at a latitude 6° 1'S and longitude 35° 7'W. The salinity was 35°/oo, dissolved oxygen was 3.8 ml/l and the temperature was 27°C. The quantity and time of collection were similar to that of *Gracilaria*.

Molluscs

We obtained stock culture of oyster, *Crassostrea rhizophora* from the Molluscs Culture Research Unit of our department. The cultivation of oyster in fishponds along with agarophytes had been iniciated at the same time.

Cultivation of marine algae

We followed the method of Krishnamurthy (1967) and Raju and Thomas (1971) with some of our own modification with reference to the materials used.

Gracillaria verrucosa

Two modules were used for fixation and growth. The first module for fixation was constructed in 25 m^2 (10 m $\times$ 2.5 m). Each end of the module constituted by two bamboo stakes fixed at a distance of 2.5 m each, to the bottom of the pond. The stakes were of bamboo poles of 2.7 m height. Nylon ropes at a regular interval of 25 cm, were tied to the stakes, thus providing an interlinked system. The algal spores weighing 20 g were safely fixed to the nylon ropes at intervels of 25 cm giving an average density of 320 g/m^2. Two such rectangular modules were fixed one at a depth of 20 cm and other at 40 cm. In the second module, nylon fishing net with 10 mm mesh size were used, with the rest of the things unchanged.

Hypnea musciformis

Nylon fishing net module was found to be suitable for cultivation. In addition to this, chambered plastic cups with 50 ml capacity were also fixed to the nylon fishing net, which supports firmly for fixation of spores and vegetative fragments, to facilitate rapid growth of algae. The chambered plastic cups are also found to be very economical, the algal materials fixed in plastic cups with chambers and were tied to the nylon ropes at equal distance of 5 cm. The modules were placed at 20 cm and 40 cm depths.

Crassostrea mangrove

In the nylon fish net rope modules, juveniles of oysters were fixed at the extremities maintaining atleast a distance of 1 m between algae and oyster. The modules for cultivation occupies nearly 25% area in the ponds.

Table 1 gives complete physico-chemical data from January to December of 1977.

Growth measurements were carried out once in 3 months for both the species and for all the modules types and presented in Tables. Net weight was calculated per m^2 and dryweight was recorded after sundrying the plants.

The increase in fresh weight, dryweight, total harvest and percentage increase in growth for *Gracilaria verrucosa* and *Hypnea musciformis* is given in Table 2, 3, 4, 5.

Production rates of G. verrucosa

The rope module cultivation at 20 cm depth showed a fresh and dryweight yield of 15.355 kg/m^2 and 1.535 kg/m^2 respectively. The increased growth was 4,798% at the end of first quarter. The rope module at 40 cm depth slightly less growth, with fresh and dryweight production of 14.825 kg/m^2 and 1.483 kg/m^2 respectively. The average production harvest per 25 m^2 in 20 cm depth was found to be 30.388 kg ard 29.063 kg at 40 cm depth.

The fish net module cultivation at 20 cm depth showed a fresh and dryweight yield of 14.240 kg/m^2 and 1.424 kg/m^2 respectively. On the other hand, freshweight yield was found to be 13.913 kg/m^2, while the dryweight was restricted only 1,391 kg/m^2. The average increase in 20 cm was 4.451% and 4.324% at 40 cm depth. The average production through this module was found to be 27.600 kg/25 m^2 for 20 cm depth.

Production rates of H. musciformis

The first module, where plastic cups with chambers were used for fixation of spores and vegetative fragments, showed following yield ; at 20 cm depth : freshweight 14.980 kg/m^2, dryweight 1.498 kg/m^2, harvested production of 30.575 kg/25m^2. The average percentage growth was found to be 4.822. Although only a marginal difference in production at 40 cm depth was observed, still it is found to be significant to make a mention here. The freshweight was found to be 14.725 kg/m^2, while the dryweight was 1.473 kg/m^2. The harvest was 28.813 kg/25m^2 with an increased growth of 4.602%.

In the fish net module, the production was more at 20 cm, showing a fresh weight of 15.163 kg/m^2, dryweight of 1.516 kg/m^2, harvest of 29.906 kg/25m^2 and the percentage increase in growth was 4.793. The same module with 40 cm depth showed a decline in production with freshweight of 13.888 kg/m^2, dryweight of 1.389 kg/m^2, harvest of 26.719 kg/25m^2 and increase in growth was 4.34 %.

It may be mentioned here that the marginal difference in growth observed at 20 cm depth with reference to production may be significant in relation to light penetration in turbid water column of basic ponds.

Growth of Crassostrea mangrove

Oysters attached to clay tiles were safely placed in the fish net module. The growth during the first month was found to be, 6.5 m with a mortality rate of 4% and at the end of the one year experiment period, oysters had attained a size of 72.14 mm with 18.49% increase in flesh content.

Economics

The cost has been considered according to the costs of fabrication of the modules, manual construction were necessary for implementation and maintenance of the system, without taking into consideration the duration of the equipments, which could be three years.

TABLE 1. *Physico-chemical data from January to December* 1970

Months	Salinidade (‰)			Oxigenic (ml/l)			pH			Matéria Orginca (ppm)			Transparencia (cm)			Temperatura (°C)		
	Min.	Max.	Med.	Min.	Max.	Med.	Min.	Max.	Med.	Min.	Max.	Med.	Min.	Max.	Med.	Min.	Max.	Med.
Jan.	30.37	35.27	31.70	4.63	4.80	3.78	8.20	8.70	7.60	4.55	4.90	4.37	25	30	26	27.0	28.0	27.3
Feb.	27.00	29.01	27.20	4.00	4.50	4.25	7.30	8.10	7.50	4.00	4.80	4.29	5	39	16	28.0	30.0	29.0
Mar.	22.00	27.00	26.00	4.20	4.70	4.30	7.10	7.90	7.30	2.80	3.40	2.80	15	70	35	27.0	29.0	28.0
Arpil	26.00	32.00	29.00	3.30	3.50	3.31	7.00	7.50	7.25	3.00	4.20	3.15	10	40	29	27.0	29.0	28.0
May	28.00	30.00	28.94	3.50	3.60	3.50	7.20	8.60	7.40	2.95	4.40	3.70	20	75	30	26.0	29.0	27.9
June	29.00	35.00	30.00	4.93	4.97	4.95	7.40	7.90	7.50	3.80	4.20	3.90	30	60	45	28.0	30.0	29.0
July	32.00	34.00	32.00	4.80	4.99	4.96	7.10	7.70	7.30	4.00	4.30	4.20	5	15	12	27.0	28.0	27.8
Aug.	26.00	27.00	26.80	4.90	4.97	4.92	8.50	8.80	8.60	2.80	3.40	3.10	5	20	16	26.0	27.0	26.5
Sept.	25.00	26.10	25.30	4.70	4.90	4.85	8.60	8.70	8.61	2.80	3.10	2.90	4	12	11	26.9	27.8	26.9
Oct.	29.00	30.00	27.00	4.20	4.80	4.29	7.09	8.20	7.16	2.45	3.09	2.50	30	70	45	27.6	29.1	27.5
Nov.	28.00	30.00	29.00	4.90	4.97	4.93	7.20	8.40	7.70	3.60	4.10	3.65	45	72	46	27.9	28.7	27.9
Dec.	29.00	32.00	29.20	4.50	4.75	4.60	7.70	8.50	7.80	3.00	4.02	3.20	35	60	57	28.0	29.5	28.7

TABLE 2. *Net culture of* G. verrucosa (20 cm deep)

Months	Start Seed Fresh Wt. (Kg/m²)	Fresh Wt. (Kg/m²)	Dry Wt. (Kg/m²)	Total Dry Wt. by module (Kg/25m²)	Harvest (Kg)	Growth (%)
January	..	0.320	0.032	0.800	..	..
April	0.320	12.800	1.280	32.000	24.000	4.000
July	0.320	14.460	1.446	36.150	28.150	4.519
October	0.320	15.000	1.500	37.500	29.500	4.690
December	0.320	14.700	1.470	36.750	28.750	4.594
Total		56.960	5.696	142.400	110.400	
		Net culture of G. verrucosa (40 cm deep)				
January	..	0.320	0.032	0.800	..	..
April	0.320	11.950	1.195	29.875	21.875	3.734
July	0.320	14.000	1.400	35.000	27.000	4.375
October	0.320	14.900	1.490	37.250	29.250	4.563
December	0.320	14.800	1.480	37.000	29.000	4.625
Total		55.650	5.560	139.125	107.125	

TABLE 3. *Rope culture of* G. verrucosa (20 cm deep)

Months	Start Seed Fresh Wt. (Kg/m²)	Fresh Wt. (Kg/m²)	Dry Wt. (Kg/m²)	Total Dry Wt. by module (Kg/25m²)	Harvest (Kg)	Gorwth (%/90 day)
January	..	0.320	0.032	0.800	..	..
April	0.320	13.750	1.375	34.375	26.375	4.297
July	0.320	14.870	1.487	37.175	29.175	4.647
October	0.320	16.000	1.600	40.000	32.000	5.000
December	0.320	16.800	1.680	42.000	34.000	5.250
Total		61.420	6.142	153.550	121.550	
		Rope culture of G. verrucosa (40 cm deep)				
January	0.320	0.320	0.032	0.800	..	..
April	0.320	13.000	1.300	32.500	24.500	4.063
July	0.320	14.600	1.460	36.500	28.500	4.563
October	0.320	15.700	1.570	39.250	31.250	4.906
December	0.320	16.000	1.600	40.000	32.000	5.000
Total		59.300	5.930	148.250	116.250	

TABLE 4. *P. S. System culture (with chambered plastic cups)* H. musciformis (20 cm deep)

Months	Start Seed Fresh Wt. (Kg/m²)	Fresh Wt. (Kg/m²)	Dry Wt. (Kg/m²)	Total Dry Wt. by module (Kg/25m²)	Harvest (Kg)	Growth (%)
January	..	0.320	0.032	0.800	..	..
April	0.320	13.120	1.312	32.800	24.800	4.100
July	0.320	15.900	1.590	39.750	31.750	4.969
October	0.320	16.300	1.630	40.750	32.750	5.094
December	0.320	16.400	1.640	41.000	33.000	5.125
Total		59.920	5.992	155.100	122.300	

P. S. System culture (with chambered plastic cups) H. musciformis (40 cm deep)

Months	Start Seed Fresh Wt. (Kg/m²)	Fresh Wt. (Kg/m²)	Dry Wt. (Kg/m²)	Total Dry Wt. by module (Kg/25m²)	Harvest (Kg)	Growth (%)
January	..	0.320	0.032	0.800	..	..
April	0.320	13.400	1.340	33.500	25.500	4.188
July	0.320	14.600	1.460	36.500	28.500	4.563
October	0.320	15.900	1.590	39.750	31.750	4.969
December	0.320	15.000	1.500	37.500	29.500	4.687
Total		58.900	5.890	147.250	115.250	

TABLE 5. *Net culture of* H. musciformis (20 cm deep)

Months	Start Seed Fresh Wt. (Kg/m²)	Fresh Wt. (Kg/m²)	Dry Wt. (Kg/m²)	Total Dry Wt. by module (Kg/25m²)	Harvest (Kg)	Growth (%)
January	..	0.320	0.032	0.800	..	..
April	0.320	14.200	1.420	35.500	27.500	4.438
July	0.320	14.900	1.490	37.250	29.250	4.656
October	0.320	15.800	1.580	93.500	31.500	4.938
December	0.320	15.750	1.575	39.375	31.375	4.922
Total		60.650	6.065	151.625	119.625	

Net culture of H. musciformis (40 cm deep)

Months	Start Seed Fresh Wt. (Kg/m²)	Fresh Wt. (Kg/m²)	Dry Wt. (Kg/m²)	Total Dry Wt. by module (Kg/25m²)	Harvest (Kg)	Growth (%)
January	..	0.320	0.032	0.800	..	..
April	0.320	12.900	1.290	32.250	24.250	4.031
July	0.320	12.700	1.270	31.750	23.750	3.969
October	0.320	14.650	1.465	36.625	28.626	4.578
December	0.320	15.300	1.530	38.250	30.250	4.781
Total		55.550	5.555	138.875	106.876	

Because of the limitation due to our experimental time of one year, we would like to be cautious in forwarding the following budget for consideration.

Basic equipment cost for the integrated system to grow algae/oyster for 1 ha

	$	$	$
400 Seawood modules ..	27.00	10,800.00	
400 Oyster modules ..	10.00	4,000.00	
Other costs ..		3,000.00	17,800.00
Operating cost for 1 ha			
3,200 tons. Seaweed seed	0.20	64.00	
1 Biologist ..	670.00	8,040.00	
5 Workers ..	63.33	3,799.80	11,903.80
Algal production ha/year (Tons)	58.330	650.00	37,914.50
Oyster production ha/year (Tons)	0.800	2.50	4,400.00
Total			72,018.30

Discussion

Analysis of physico-chemical characteristics, increased growth of agarophytic algae and meat content of oyster clearly indicate ecological possibilities and economical feasibilites of integrated culture in North-east Brazil.

Osmotic stress has always proved to be a barrier of possible transplantion of marine algae to laboratory situation and observations of increased growth of *G. verrucosa* and *H. musciformis* in estuarine environment, overwhelmingly suggest that intertidal agarophytic algae could possibly be cultivated circumventing a salinity shift.

Oswald *et al.* (1975) suggested that the production of 58.330 tons/ha/year of algae and 0.800 tons/ha/year of oyster meat were the estimate for economic viability of any pilot plant production, which could be expected to yield monetary return of US$ 42,314.00 for a capital investment of US$ 26,314.00. Since our intention is also to encompass economic side of the project of pilot plant, the utilization of already existing ponds, the low-cost involved in evolving modules, and the production rate of *G. verrucosa* which is 1 458 kg/m^2 of dryweight and *H. musciformis* 1.469 kg/m^2 readily as compared to the poor production rate of 298 gm/m^2 of dryweight in intertidal zone, the natural habitat of these algae.

The observations of increased production rate of agarophytic algae and oyster, in addition to being the first reports from North-east Brazil, also suggest possibilities of further intensive cultivation.

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STUDIES ON MASS CULTURE OF MARINE YEAST *CANDIDA* SP. FOR FEEDING ZOOPLANKTON AND SHRIMP LARVAE

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ABSTRACT

The Microorganisms Culture Project includes the cultivation of single cell microorganisms with emphasis on the mass production of marine yeast by using the batch culture system. This yeast is used in the culture of zooplankton and shrimp larvae. Since 1975 intensive efforts have been placed on the utilization of marine yeast from local marine habitats. The first step to be undertaken was the isolation and selection of useful strains from samples collected from shrimp culture sediments and Kuwait coastal seawater. Goto's medium was used during the selection. The strain with the highest growth rate was selected for mass production. A scale-up system was used for the mass production of the selected strain (600 l). Pure seed cultures (5%) were prepared from pure slant cultures passing through 50 ml, 10 l and 50 l cultures, and inoculated into a 1 m^3 culture tank containing 600 l of synthetic medium. It contained glucose or sucrose as the carbon source, urea as the nitrogen source, and phosphate supplement. Temperature was maintained at 30°C, pH at 4.5, and salinity at 30°/oo so that the productivity of the 10 l, 50 l and 600 l cultures was approximately 15, 20 and 10 g/l (on dry weight basis) respectively. Taxonomical studies revealed that the selected strain was *Candida* sp. It could grow at high temperatures (upto 50°C), and optimum growth temperature was 30°C. Also it showed good growth at wide range of salinities (0.0‰—40‰). Finally, its chemical composition showed its richness in crude fat, protein and the amino acids lysine and leucin.

INTRODUCTION

'OCEAN DEVELOPMENT' is a term which implies much about the hopes of mankind for the 1980's. This term will be defined here as the sum of those efforts directed toward the realization of plans designed to bring part of the great productive capacity of the ocean under the control of mankind.

As marine yeasts are considered to be an important category of marine microorganisms, it was decided to concentrate on it, with particular reference to mariculture feeding systems. A well known system for feeding fish and other larvae by the use of *Chlorella* (marine species) has been put into practice by Hirata, 1974. Microorganisms such as diatoms were also tried, but many technical problems have arisen, particularly in large scale high density cultures. Also freshwater microorganisms (*e.g. Chlorella, Scenedesmus*) and baker's yeast have been supplied as food for marine zooplankton cultures. However it was found that the cells of these organisms disintegrate, causing pollution of the cultures under high osmotic pressure of seawater (Kawano and Ohsawa, 1971).

In order to solve the problems of cell disintegration caused by osmosis and the ensuing pollution, it is believed that the utilization of marine microorganisms is the best answer. Thus many problems will be avoided especially when mass cultures are considered. Marine yeasts are ideally suited to provide good conditions for the growth of marine organisms either directly for zooplankton and indirectly for young fish larvae.

The discovery of marine yeast goes back to 1894, when Fisher separated red and white yeast from the Atlantic Ocean and identified them as *Torula* sp. and *Mycoderma* sp.

Following Fisher's discovery, many other workers such as Hunter (1920), Bhat (1955 a ; 1955 b), Suehiro (1960) and Uden and Fell (1968) isolated marine yeasts from different sources *viz*. seawater, marine deposits, seaweeds, sea fish, marine mammals and sea birds. From these studies it was found that marine yeasts do not belong to a specific genus or group of genera, but that they are distributed among a wide variety of well known genera such as *Candida, Cryptococcus, Debaryomyces, Pichia, Hansenula, Rhodotorula, Saccharomyces, Trichosporon* and *Torulopsis*. Thus marine yeasts do not belong to a special group but are species and/or strains from different genera which happen to possess two particular characters. These characters are (i) salt resistance and (ii) carbohydrate assimilation rate. Regarding salt resistance activity, Bhat (1955 b) reported the growth of yeasts isolated from the Indian Ocean in media containing high NaCl content (9-12%) and phosphate content (8-26%).

Although marine habitats are considered to be unfavourable for the existence and growth of yeasts in general, it was found that yeasts isolated from saline sources can assimilate different kinds of carbohydrates at high rates. Ahearn (1962) made an attempt to distinguish the types of carbohydrates that could be assimilated by marine yeasts. He used thirty types included hexoses, pentoses, disaccharides, trisaccharides and polysaccharides. It was found also that not all marine yeast can be used for mariculture because some species secrete substances which are toxic to man and animals (Gentles *et al*., 1969 ; Madri *et al*., 1966). The yeasts chosen for mass production must be non-pathogenic.

Although the origin of marine yeasts is not yet clear (are they true inhabitants of the sea or are they merely transients ?), they do show distinct differences from other forms.

The utilization of marine yeast for feeding of shrimp larvae and zooplankton has been demonstrated by some workers. Furukawa (1972), Furukawa and Hidaka (1973) and Furukawa *et al*. (1973) used marine yeast as food for the production of larvae of *Penaeus japonicus*. The biochemical and ecological characteristics of the marine yeast used for this work was also studied by Kawano and Ohsawa (1971). On the other hand yeast was also used for the mass production of rotifers *Brachionus plicatilis* (Furukawa *et al*., 1973 ; Kawano *et al*., 1976).

Mass culture and production of marine yeast was not established until recently, when Kawano (1968) started mass culture of marine strain of *Saccharomyces* sp. and tested its practical application to mariculture. Some of the practical culture techniques are reviewed by Hopp (1976).

Kuwait is located in an arid zone that is characterized by its hot summer. Temperatures reach up to 45°C in the hottest months with sand and dust storms. Salinities may be over 40 ‰. Also, salinities of up to 44‰ have been observed in Kuwait Bay (Mathews, per. comm.). In order to carry out successful culture work in such extreme environments, it is essential to isolate and culture marine yeasts capable of tolerating the local conditions.

In this paper the isolation, screening and culturing of marine yeast under Kuwait's peculiar environmental conditions and the applications of the mass cultures of yeast for feeding zooplankton (*Brachionus plicatilis*), and shrimp larvae (*Penaeus semisulcatus* and *Metapenaeus affinis*) are presented.

Both authors wish to express their deep gratitudes to Mr. Nazar Hussain, Head of the

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MATERIAL AND METHODS

Screening of useful marine yeast strains

In order to obtain useful strains of marine yeast for mass culture, marine yeast were isolated from different sources *viz.* shrimp culture sediment, rotifer culture filtrate and natural seawater. Such sources are thought to be richer in marine yeast cells than others. Samples were collected in sterile bottles, transferred to the laboratory and placed in the refrigerator at 5°C and stored.

Marine yeasts were isolated by applying the dilution plate technique (Iizuka and Goto, 1973) where a series of dilutions were made. Goto's peptone yeast extract agar medium was used (Goto *et al.*, 1974) and triplicates were prepared for each dilution. Yeast cells were cultured at 30°C for 24 h. Pure colonies were then transferred to slants with Goto's medium. The pure slant cultures were stored together, labelled and kept as stock for further experiments.

Also, the monocolony selection technique was applied whenever main cultures showed low activity. Then growth activities of the pure colonies were compared and the best growing one was again selected for mass culture.

Stock cultures were always stored in the refrigerator at 5°C. Sub-cultures were usually carried out every three months in order to maintain the colony's activity.

The growth of pure isolated colonies of yeast strains was compared. Total production rate of each strain was determined by suspending the entire growth of each slant into 5 ml of sterile 50% filtered seawater which was subsequently added to 50 ml of basic culture medium (Table 1) in a 250 ml Erlenmyer flask. Triplicates were used for each strain; the flasks were placed on a reciprocating shaker (Psycrotherm Incubator Model G-27; New Brunswick Scie. Co., Inc.) at 30°C with a shaking rate of 120 strokes per minute. After 24 h total production rate was obtained by determining the total dry weight (g/l). The strain showing highest total production rate was selected for the scale-up culture system.

TABLE 1. *Culture Medium for Marine Yeast*

Ingredients		Basic Medium	Mass Production Medium
Carbohydrate (glucose or sucrose)	..	5 g	50 gm
KH_2PO_4	..	0.1 g	1 g
Na_2HPO_4	..	0.1 g	1 g
Urea	..	0.2 g	2 g
Vitamin mixture*	..	1.0 ml	10 ml
Cane molasses	..	—	3 ml
Penicillin	..	10,000 i.u.	—
Tetracycline	..	—	100 mg
Filtered seawater	..	100 ml	1000 ml
pH**	..	4.5	4.5

* cf. Iizuka & Goto, 1973.

** Adjusted with 10% HCL Solution.

In order to set up the optimum growth conditions for the selected marine yeast strain, the optimum pH, temperature and salinity were determined. For determination of the appropriate pH value, the total production rate of the selected strain was determined at initial pH values of 2, 3, 4, 5, 6 and 7 and results were compared. The total production rate of the selected marine yeast strain was also determined at the following temperatures: 25, 27, 30, 33, 35, 37, 40, 45 and 50°C. Similarly total production rate was also determined at the following salinities; 10, 20, 30 and

40‰. In all experiments, basic culture medium was used and growth was compared after 24 h.

Flask culture

The Flask culture of marine yeast was an essential step for scaling-up of the culture system to reach the large volumes required for successful culture. Flask culture also provided a pure source of the selected yeast strain for mass culture and it was carried out during each mass culture cycle.

Prior to its use for flask culture, the selected marine yeast strain was stored in the refrigerator at 5°C, and sub-cultured at short intervals in order to keep it in good condition. For the preparation of the flask culture, sterile Goto's agar slants were inoculated from stock. The entire growth of each slant was then suspended in 5 ml sterile 20‰ seawater. This was subsequently added to sterile 50 ml seed culture medium in a 250 ml Erlenmyer's flask. The flasks were placed on a reciprocating shaker. Conditions were similar to those for mono-colony cultures.

Jar fermentor culture

Culture in the jar fermentors (Microferm MF—207 New Brunswide Sci. Co., Inc.) was also used in scaling up the culture cycle; it was the final step between flask culture and full pilot-scale production of the marine yeast. The jar fermentors provided a full and abundant source of 'seed' yeast for full scale operations. Aseptic conditions were observed during preparation of the seed yeast. The jar fermentor culture was started by inoculating 500 ml of pure marine yeast seed into 10 l of basic culture medium in 14 l jar fermentor. The culture was maintained for 24 h. Temperature was adjusted at 30°C, with initial pH value of 4.5, an aeration volume of 10 l/min and an agitation rate of 400 rpm.

Small scale continuous culture

It is always convenient when waste materials, from other activities can be used for culturing yeasts. In the Mariculture and Fisheries department, filtrates obtained from other experiments *e.g.* filtrates obtained from rotifer culture were used. Accordingly a system has been established for utilization of such filtrate (Fig. 1). The culture was started by adding 1,000 ml of rotifer culture filtrate to 10 l of basic culture medium. The culture was provided with continuous aeration and agitation and the temperature was kept at 30°C. After 24 h, as the marine yeast in the rotifer culture

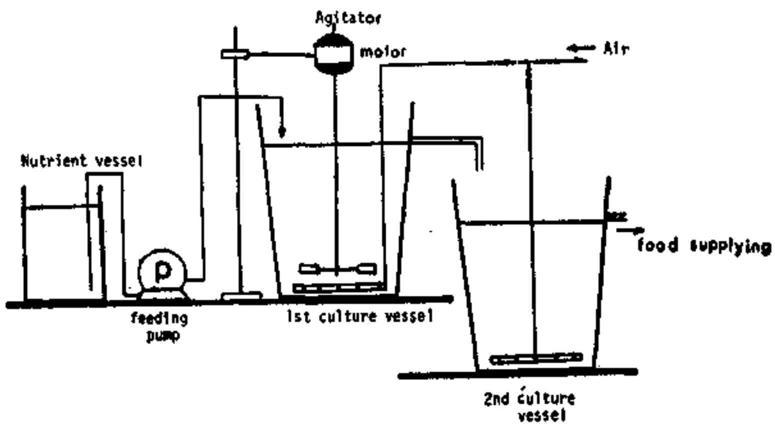

FIG. 1. Continuous culture system of marine yeast.

filtrate flourishes, 10 1 of basic culture medium was pumped in for 20 h at a rate of 8.6 ml/min. After 24 h the first unit was filled and as the addition of synthetic medium starts, the output of the culture of marine yeast in the first culture overflowed into the second vessel which was also provided with aeration. The total production rate (dry weight g/l) and the carbohydrate content were determined. After four days the culture was stopped as it showed decline in growth.

Pilot-scale culture

In order to scale-up the culture system for mass production of marine yeast, two types of locally made iron tanks (Fig. 2) of 75 l and 1 m^3 capacity were used. Seed culture was prepared by subsequent transfer of 10 l of

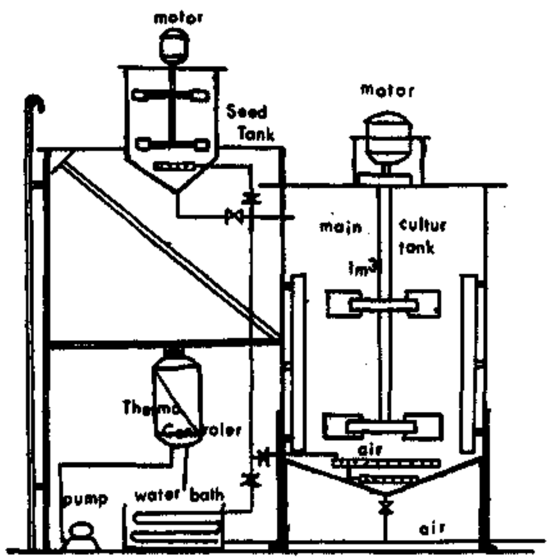

FIG. 2. Mass production system of marine yeast.

marine yeast (cultured for 24 h in the Jar fermentor) to 40 l of synthetic medium in the 75 l culture tank. Temperature was kept constant at 30°C throughout and provided with aeration. The agitation speed was kept at 100 rpm. Subsequently 50 l of 24 h old 'seed' culture was transferred to 550 l of synthetic medium, in a culture tank with a volume of 1 m^3. This was the main culture tank for marine yeast mass production. Temperature was adjusted to 30°C, aeration at a rate of 10 l/min and agitation speed was 400 rpm. Total production rate (dry weight, g/l), residual carbohydrate and final pH value were determined. This was done for both small scale culture and the pilot-scale cultures.

Method of determination of dry weight

The total production rate of the culture of marine yeast was detected by measuring the optical density at 610 mm by a colorimetric method. A standard curve was prepared by plotting different dry weights against the corresponding measured optical density. This was made by preparation of a series of solutions with known dry yeast content, the optical density for each solution was measured and was plotted on the graph. A straight line was obtained from which an equation was derived for the calculation of dry yeast content.

Method of reducing carbohydrate determination

The reducing carbohydrate content was determined by using 3.5-dinitro-salicylic acid reaction colorimetric method. A standard curve has been prepared for the determination of reducing carbohydrate content of unknown samples. Growth rate coefficient was calculated from the equations of Seki (1976).

$$U = \frac{0.93\,(\log X - \log X\,1)}{0.31\,(t_2 - t_1)}$$

The pH values of all samples were determined by using an orion research model-20 digital and/or an orion research Ionalgzer, model-407A pH meter.

Nutritional evaluation of the selected marine yeast

A pure washed freeze dried sample of the selected marine yeast strain was sent to the Japan Food Research Laboratories, Tokyo, Japan for nutritional evaluation and chemical analysis.

Growth analysis of the 10 l *culture of marine yeast*

Growth analysis of 10 l culture of the selected marine yeast strain was carried out in systems with controlled and uncontrolled pH. Preparation of culture followed the same procedure used for the scale-up culture system. The total production rate (dry weight g/l), reducing carbohydrates, and pH values were checked at 2 h intervals for a period of 24 h. The culture efficiency was also calculated for each corresponding reading.

Taxonomical studies on the selected marine yeast, MFD-Y-St/03 strain was carried out. It followed the procedures of Izuka and Goto (1973) and Lodder (1974).

RESULTS

Screening of useful marine yeast strain

Over 50 marine yeast strains have been isolated from the different samples collected. When the growth of these strains was compared, results revealed the selection of the strains with highest total production rate. It was referred to as MFD-Y-St 03. This strain was identified as a species of the genus *Candida*, on the basis of the taxonomic characters shown in Table 2.

Optimum growth conditions of Candida *sp. strain MFD-Y-St* 03

For the determination of the optimum growth conditions of *Candida* sp., the influence of different temperatures, pH and salinities were determined. Growth was studied at the following temperatures 25, 27, 30, 33, 35, 37, 45 and 50°C (Fig. 3). It was found that maximum growth was obtained at 37°C and growth declined as temperature increased above,

TABLE 2. *Description of* Candida *sp. MFD—Y—St* 03

Growth in glucose—Yeast extract:peptone water :
After 24 h at 25°C the cell was avoided (3-4.5) × (5-7.5) micr. No dull pellicle is present.

Growth on glucose—Yeast extract-peptone agar :
After one month at 25°C the culture is cream-coloured, semi-dull, soft, almost smooth.

Dalman plate cultures on corn meal agar :
Well developed formation of pseudomycelium; chlamydospores are formed as well as trye mycelium-Arthrospores, ascospores, telospores and haliotospores were not formed.

Fermentation :
Glucose, sucrose were fermented.

Assimilation of carbon compound :
Glucose + lactose + Trehalose +
Fructose + Sucrose + starch +
Xylose + Maltose + Dextrin + Glycerol +

Assimilation of potassium nitrate :
Positive.

Ammonium :
Positive.

Production of starch :
Negative.

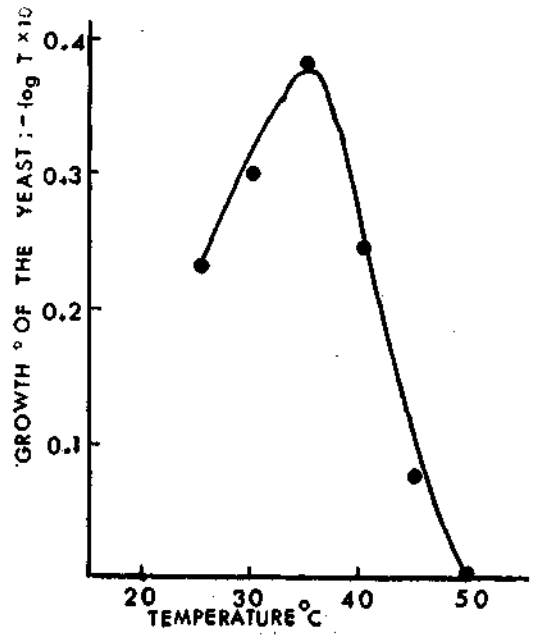

FIG. 3. Influence of temperature on the growth of *Candida* sp.

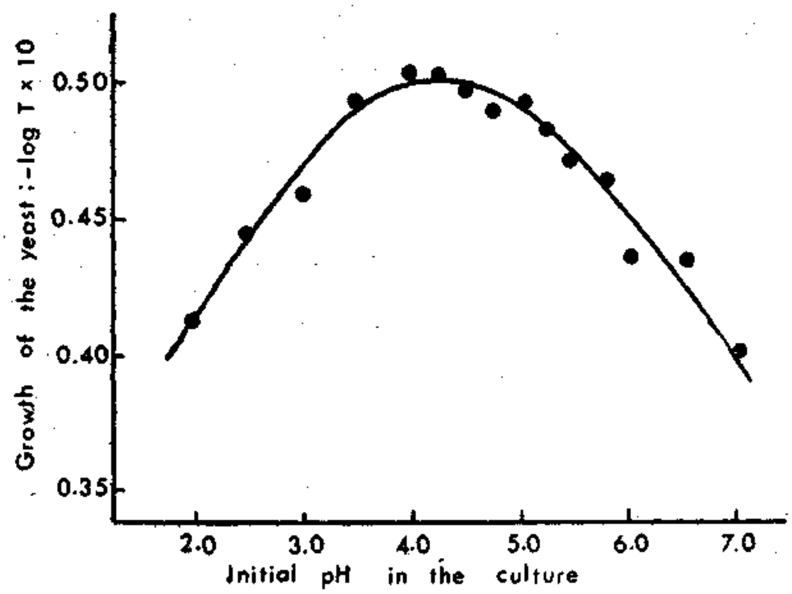

FIG. 4. Influence of pH on the growth of *Candida* sp.

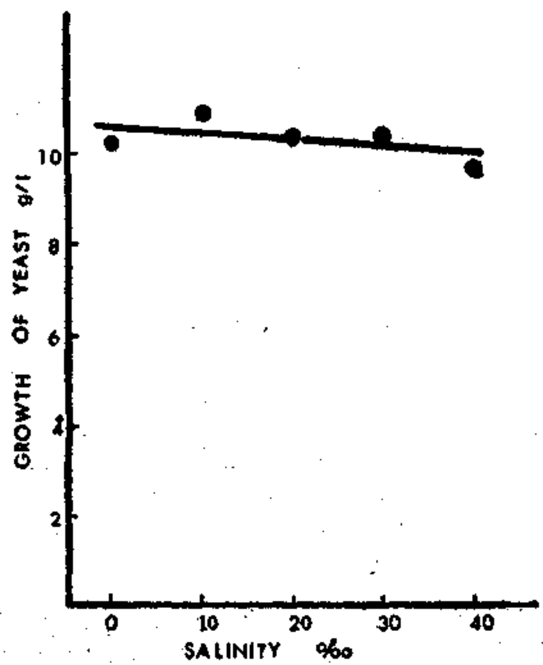

FIG. 5. Influence of salinity on the growth of *Candida* sp.

or decreased below this temperature. Yeasts usually have optimum growth temperatures from 25-30°C. However, strain MFD-Y-St 03 shows a much higher optimum growth temperature. Therefore, it is more suitable for the Kuwait climate and for other high temperature areas.

As the relationship between growth and pH value was considered, it was found that optimum growth was reached at pH values of 4.0 and 5.0 (Fig. 4).

On the other hand, when the total production rate of *Candida* sp. was determined for cultures with different salinities (Fig. 5) no significant difference in growth was found when salinity varies from 0‰—40‰.

Growth analysis in the jar fermentor

The two growth curves of *Candida* sp. MFD-Y-St 03 under the controlled pH and uncontrolled pH conditions are shown in Fig. 6. It is clear that growth in the controlled pH system is higher than that in the uncontrolled pH system. Also, carbohydrate was assimilated at a higher rate, in the controlled pH system.

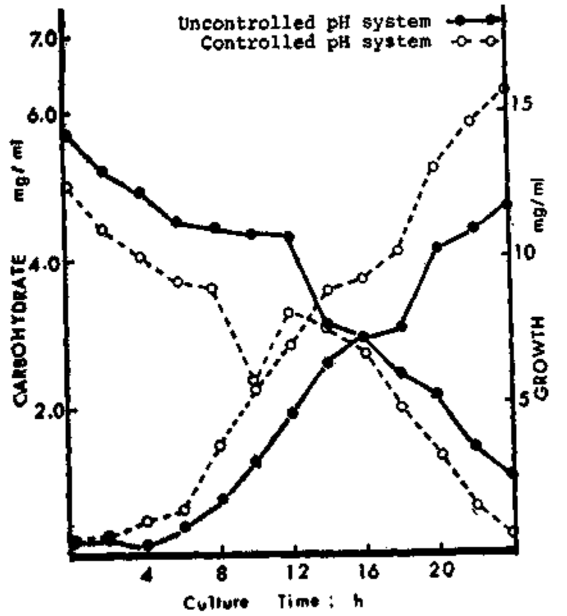

FIG. 6. Influence of pH on the growth and carbohydrate assimilation of MFD-Y St. 03.

The growth coefficient for *Candida* sp. MFD-Y-St 03 was determined. It was found that maximum coefficient for the controlled pH culture occurred after 20 h, while that of the uncontrolled pH culture was occurred from 14-16 h. However when total production rate for both cultures was calculated (Table 3), it was found that total production rate is higher for the controlled pH culture (15.5g/l). Although the maximum growth coefficient of uncontrolled pH culture was at 14-16 h (in other words the optimum pH for culture was reached at the time), it declined subsequently resulting in low total growth. This low growth is attributed to the instability of the pH value of the culture. Accordingly, the controlled pH system is recommended.

The possibility of utilizing waste filtrates produced by other marine culture activities at the Mariculture and Fisheries Department was explored. A system in which the main culture could be maintained is shown in Fig. 1. Total growth (dry weight g/l), carbohydrate content and pH value for 6 h in the lst, 2nd, 3rd and 4th days were measured. Fig. 7 shows that, in the first 24 h the marine yeast grew and reached its maximum growth; subsequently the growth was constant at this time the ratio of input *i.e.* of nutrients and output (*i.e.* yeast/harvest in the 2nd phase) was 50%. After 76 h, the growth rate started to decline. Carbohydrate content was high in the first 24 h and then declined.

TABLE 3. *Coefficient growth speed, and total production rate of controlled pH and uncontrolled pH system*

Marine yeast culture	Umax. in exponential growth phase	Total productivity (g/l)
Controlled pH system	1.1	15.5
Uncontrolled pH system	1.2	11.5

These results show the possibility of utilizing the mariculture waste waters for marine yeast production and that for short periods, such a continuous culture system would be stable. This system is quite efficient for continuous feeding of zooplankton with suitable yeast cells.

Pilot scale marine yeast culture

The scale-up of the marine yeast culture system was designed mainly to meet the increased demand for utilizing marine yeast as an essential live food for mariculture, with particular emphasis on zooplankton culture, rotifer (*Brachionus plicatilis*) culture and culture of shrimp larvae.

The pilot culture tank has a capacity of 1 m³ and the seed culture tank has a capacity of 75 l (Fig. 2). These tanks are locally made of iron and are coated with a special seawater resistant non-toxic paint. The total volume of culture in the main tank was 600 1 and 50 1 in the seed culture tank.

This system has been in operation over a period of two years and was found to be satisfactory.

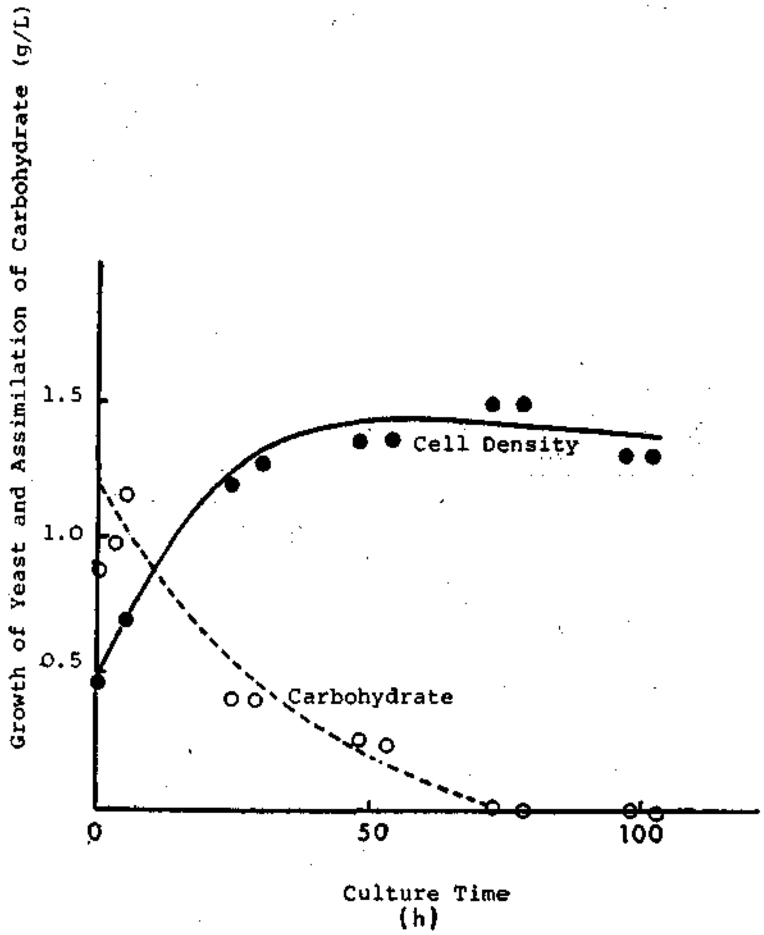

FIG. 7. Progress of marine yeast in continuous cultivation.

TABLE 4. *Total growth (dry weight in g/l provides an estimate of yield) g/l residual carbohydrate efficiency and final pH value, for, 600 l and 50 l cultures during the seasons* 1977/78 *and* 1978/79 (The data presented averages over the two seasons)

Culture	Dry weight	Efficiency	Residual carbohydrate mg/ml	Final pH values
50 lit	20.0	40	0.015	3.5
600 lit	10.0	20	0.013	3.4

Table 4 shows that the total yield of the 50 1 culture (20 g/l) is higher than that of the 600 1 culture (10 g/l). Although the same culture medium and culture conditions were applied for both cultures, the efficiency is higher for the seed culture tank than the main culture tank. This could be attributed to a lower degree of stirring and water movement in the larger tank. If so, this problem may be avoided by increasing the dissolved oxygen concentration in the larger culture.

Chemical composition of marine yeast Candida *sp. MFD-Y-St* 03

The chemical composition, including the general composition (Table 5) and amino acid content (Table 6) of *Candida* sp. was analyzed by the Japan Food Research Laboratories, Tokyo, Japan. When those data were, compared with those of Kawano (1971) it could be seen that the crude fat content of *Candida* sp., strain MFD-Y-St 03, was almost double that of the strain ASY-4011 used by Kawano (1971). Similarly, the nitrogen free extract obtained from MFD-Y-St 03 and ASY-4011 was twice the value of that obtained from *Saccharomyces* sp. Table 6 shows that *Candida* sp. contains two of the essential amino acids: lysine and leucine. Those amino acids were found at concentrations of about x 1.24 and x 1.18 obtained from strain ASY-4011. The presence of those two essential amino acids is thought to be important for mariculture purposes.

TABLE 5. *General chemical composition of Marine yeasts and Baker's yeast*

Yeast type	Marine Yeast		Baker's yeast
	Candida sp. MFD-Y-St 03	*Torulopsis* sp. ASY-4011*	*Saccharomyces* sp.
Crude protein	34.9	32.13	48-63
Crude fat	2.1	1.05	7-7
Crude ash	9.1	9.82	7.0-7.5
Nitrogen, free extract	53.8	57	27-36

* Compiled from Kawano and Ohsawa (1971)

TABLE 6. *Amino acid composition of marine yeast*

Yeast type/Amino acid	*Candida* sp. MFD-Y-St 03	*Torulopsis* sp. ASY-4011*
Lysine	2.30	1.86
Histidine ..	0.60	0.53
Phenylalanine ..	1.56	1.21
Tryosine ..	0.75	0.91
Leucine ..	2.15	1.82
Iso-leucine ..	1.54	1.14
Methionine ..	0.41	0.47
Valine ..	1.66	1.29
Alanine ..	1.88	1.80
Glycine ..	1.36	1.40
Proline ..	1.21	1.58
Glutamic acid ..	3.90	4.33
Serine ..	1.49	1.64
Threonine ..	1.71	1.56
Aspartic acid ..	3.07	3.16
Tryptophane ..	0.35	—
Cystine ..	0.37	—

* These data were complied by Kawano and Ohsawa (1971)

DISCUSSION

There has been increasing demand in recent years for the utilization of live marine micro-organisms in mariculture. Some workers have been using freshwater microorganisms for mariculture (*e.g.* Imada *et al.*, 1977) who studied the feeding of shrimp larvae on bread yeast but found that it was not suitable as a food because it is deficient in the essential fatty acids content. The MFD-Y-St 03 strain of *Candida* sp. was used primarily for zoo-plankton and rotifer culture; however the production was presented to shrimp in culture tanks and seems to have increased the growth rate of the shrimp (Farmer, pers. com.). Kawano (1971) found that the nitrogen free extract content of *Candida* sp. strain ASY-4011, is much higher than that of Baker's yeast or of those yeasts isolated from fresh-water. However, the physiological and bio-chemical characteristics which separate marine and freshwater yeasts are not yet clear but it is perhaps rather surprising that at least one marine yeast strain appear to show the same growth rates in salinities ranging from 0-40‰. Marine yeasts are an essential component of microbial detritus in both marine and fresh-water environments. The observations demand further attention. Marine yeast unlike the marine bacteria (which appear to belong to species distinct from freshwater bacteria) appear to be strains of species taken from freshwater.

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MASS PRODUCTION OF ROTIFER *BRACHIONUS PLICATILIS* BY USING MARINE YEAST PART 2 : OUTDOOR CULTURE

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ABSTRACT

The culture of rotifer (*Brachionus plicatilis*) microorganisms as a source of live food for fish and shrimp was started at the Mariculture and Fisheries Department in November 1975.

Outdoor culture was established by utilizing concrete tanks, each of 10, 14 or 20 m^3 capacity. Each tank was provided with heating system (so that temperature was held at 25-28°C) ; strong aeration and agitation (except for 14 m^3 tanks) (to allow for equal distribution of marine yeast) was also provided 10% of culture volume. The culture usually starts by introducing *Chlorella* (at a density of 10×10^6 cells/ml) into 90% of culture volume brackish water (with rotifer density of 30-50 individuals/ml) to each tank. The only food supplied to the rotifer culture was the marine and baker's yeast. The yeast was pumped into the culture tanks for 20 h/day. The average density maintained was 200 individuals/ml. The supply taken from the rotifer culture tanks average $1{,}800 \times 10^6$ rotifers per day and the conversion ratio of yeasts to rotifers was 0.84.

During the course of the study, it was found that the rotifer culture filtrate could be used for marine yeast culture, as it was enriched with nutrients providing suitable conditions for growth of localized marine yeast. It was also noticed that some green algae which were usually attached to the wall of the tanks or floating freely in the culture, play an important role in the filtration of the culture and in maintaining the ecosystem equilibrium.

INTRODUCTION

CULTIVATION of rotifer is an important process for the production of a nutritional medium for fish larvae upto 45 days after hatching. This is because : (1) The small body size of rotifer, is suited to the small mouth openings of fish larvae aged 0-45 days. (2) Many fish larvae feed naturally on rotifer during their first weeks of life. (3) Large scale rotifer cultures may be conducted with relative ease.

Three systems are applied for mass production of rotifers at the Mariculture and Fisheries Department of Kuwait Institute for Scientific Research (Kawano *et al.*, 1978). These systems are : (1) The batch culture method (originated by the Seto Interbary Sea Farming Association of Japan) which requires a three-day culture period, using 0.5 m^3 transparent polycarbonate tanks with *Chlorella* and baker's yeast as food. (2) The continuous culture system, which was started at the Mariculture and Fisheries Department in 1977 (Al-Mattar *et al.*, 1979 ; Kawano *et al.*, 1978), rotifers are fed only on bread yeast. (3) The outdoor culture system, based on the use of outdoor culture tanks for rotifer production, is considered to be one of the most successful modern developments. Japan is the leader in this field ; fresh baker's yeast and *Chlorella* are used as basic nutritional medium for high density pond culture system (Endoh, 1977 ; Fukusho, 1976).

However, at the Mariculture and Fisheries Department, another method of feeding has been applied. This method which is based on a mixture of baker's yeast and cultured marine yeast, has been used and is more flexible under the climatic extremes typical of local conditions in Kuwait. There are two main reasons for not using only baker's yeast: first, it is not available in fresh condition, being stored for long periods which decreases its viability, and second, although it may be dissolved in fresh water its suspension in sea water or in rotifer cultures causes cell breakdown owing to osmotic differences between cell contents and sea water. The food ceases to be alive and breakdown products become substrates for a wide variety of bacteria; the culture medium then becomes less favourable for growth of the rotifers. However, the marine yeast cultures and the rotifer cultures are iso-osmotic and the yeast remains alive and may even multiply in the rotifer culture itself. The rotifer culture is therefore clean and more easy to maintain.

All authors wish to express their deep gratitudes to Mr. Nazar Hussain, Head of the Mariculture and Fisheries Department for encouragement. Our thanks are due to M. U. Ukawa for his help in planning this research, Dr. C. P. Mathews for reading the manuscript. We are thankful to all the staff members of Microorganisms Culture Project for their assistance.

Material and Methods

Source of cultured rotifer

The rotifer used for outdoor culture was previously collected from one of the fish culture pond at Fintas-Kuwait, three years back. This pond was previously tried for culturing hamoor (*Epinephelus tauvina*). However, the culture was not successful and therefore the empty tank was filled with fresh water. Under the influence of evaporation, the salinity of water increased to 5‰ and a naturally occurring rotifer population flourished. This freshwater rotifer was collected and then gradually acclimatised to brackish water. It was then regularly cultured in water of 30-32‰ salinity and used as a seed culture for the mass culture of rotifers.

Food supplied for cultured rotifers

The rotifer culture is usually started by inoculation of a culture tank with rotifers from the seed cultures. The culture tank is filled with water (90% of tank volume culture capacity) of salinity 30-32‰, and *Chlorella* culture (10% of tank volume culture capacity) with density of $10\text{-}20\times10^6$ cells/ml. The addition of *Chlorella* is just for the sake of ecosystem equilibrium. The feeding starts from the very first day, when marine yeast and dry baker's yeast are supplied in the ratio of 2 : 1. The amount of food supplied is calculated as shown in Fig. 1. However on the first, second and sometimes on the third day only half the above quantities of yeasts may be supplied. This is because the rotifers may require sometime to adapt themselves to the new environment; hence their ability to feed is lower than usual. Therefore supply of half the usual quantities of yeasts is often sufficient to meet the rotifers food requirements. The lower food supply leaves no residues which could be accumulated. As the cultured rotifers become more adapted to the medium, they starts to attain their natural ability for feeding and growth; hence, the full quantity of yeast are supplied daily.

The outdoor cultures are being fed with marine yeast and baker's yeast by applying a continuous feeding system: The yeast is pumped constantly for 20 h/day into the rotifer culture tanks. The calculated quantities of marine yeast and bread yeast are mixed together and placed in conical plastic containers (with a capacity of 70 l) and pumped for the requisite period.

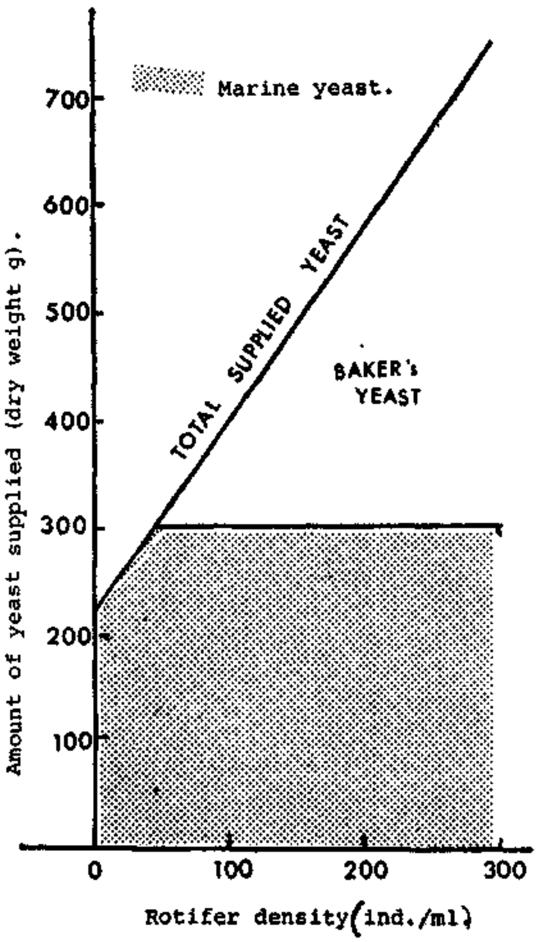


FIG. 1. Yeast supply to rotifers culture in 10m³ tanks.

Culture Conditions

After several trials of culture experiments the conditions for outdoor cultures were clarified and finalized. It was found that temperature should be kept constant at 27°C. This is done by use of a heating system : where warm water is circulated inside galvanised pipes of 3" diameter which are submerged in each tank to keep the temperature of the cultured water around 27°C. Agitators are installed in each tank to prevent the accumulation of detritus and to ensure uniform distribution of yeasts inside the culture tanks. Aeration pipes are spread over the bottom of each culture tank to increase the ratio of dissolved oxygen which plays an important factor in the growth rate of rotifers (Fig. 2 and Fig. 3 respectively). The salinity of the water used is around 32‰. Suitable culture water was made by mixing seawater and freshwater in the ratio of 4 : 1.

Culture tanks used

Various kinds of concrete tanks were used for the rotifer cultures : a-three tanks with a capacity of 10 m³ each ; b-five tanks with a capacity of 14 m³ each, and c-two tanks with a capacity of 20 m³ each. The main tanks used are those of 10 m³ capacity and most of the results given here are obtained for cultures from these tanks. However, the 20 m³ tanks were used when the demand for rotifers exceed the capacity of the 10 m³ tanks to supply the rotifers.

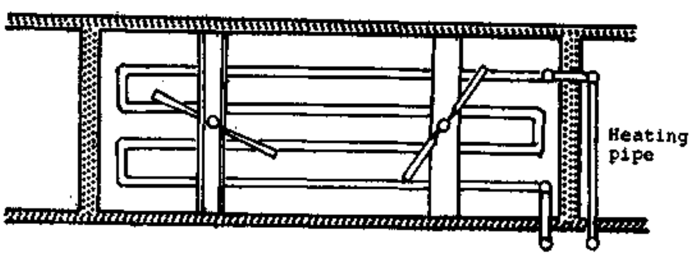


FIG. 2. Top view of outdoor concrete tank (20 m³) heating and agitation system.

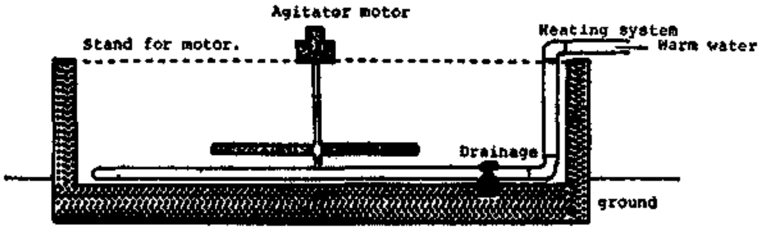


FIG. 3. Side view of outdoor concrete tank.

Culture procedure

At the beginning of the culture, the tank is filled with brackish water (90% of the tank volume culture capacity) and *Chlorella* water (10% of the tank volume culture capacity) with density of 10-20 × 10^6 cells/ml. Then rotifers are introduced so that a density of 50 individual/ml is achieved. Feeding with mixture of marine yeast and baker's yeast in the ratio of 2 : 1, is started. The yeast mixture is adjusted to 50 l by the addition of water (salinity 32‰) and then placed in 70 l conical plastic container. Yeast is withdrawn continuously and supplied to the rotifer culture by pumping for 20 h/day. After several days the density of rotifers increase upto 200-300 individuals/ml; then rotifers are harvested according to the requirements of the fish culture and other maricultures. Usually 15-20% daily culture is harvested by draining using a 69 micron mesh seive. At the time of harvest, culture density usually ranges from 200-300 individuals/ml and pH is around 7.8 ±0.5. The culture volume is then adjusted by the addition of water (salinity 32‰). This type of culture usually lasts for 40-60 days, and then cleaning should take place. After cleaning of the culture system the culture is re-started. It was found that it is important to re-start the rotifer culture as less than 20% of the rotifers carried eggs after this period. Furthermore, the culture usually gets contaminated with a ciliate which was found in several cultures after long culture period. On examination, the ciliate was found to be *Euplotes charon.* A further difficulty after long culture periods arises from the marked increase in sediments on the side walls and the bottoms of the culture containers. It was also noticed that the rotifer culture tanks harboured a considerable growth of sea weeds and marked increase in sediments on the side walls and bottoms of the culture containers after long periods. However, the sea weed was found to be beneficial to the rotifers. It clears the culture water by acting as a filter and also maintains the culture ecosystem in an equilibrium which appears to enhance growth of the rotifers.

RESULTS

During the 1979 culture season, rotifers were supplied for fish and shrimp culture mainly from the outdoor rotifer culture system. Rotifers were cultured in outdoor tanks of different capacity, three 10 m^3 tanks, five 14 m^3 tanks and two 20 m^3 tanks. The production rate from these culture tanks were compared with each other (Table 1). The items determined were :

1. The tank efficiency which is defined as daily production of rotifers per ton of culture,
2. The tank productivity which is defined as the total dry weight of rotifers per season/day per tank,

3. The conversion ratio, which is defined as :

$$\frac{\text{Total dry weight of rotifers/season/tank}}{\text{Total supplied dry weight of yeasts/season/tank}},$$

4. The highest rotifer density obtained for each tank, and
5. The pH value.

Results during culture period of 90 days were compared for the three outdoor cultures. In the 10 m^3 culture the maximum density that could be obtained was 390 individuals/ml, and the daily production was 20.61×10^6 individuals/ml. On the other hand the total production was found to be 51.36 kg/season/tank, on a dry weight basis and the total weight of dry yeasts supplied was 32.77 kg/season/tank. Accordingly, the conversion ratio of rotifers in the 10 m^3 culture tanks was 0.64. The reason of the high results will be explained in the discussion. pH value of the culture ranged from 6.8 to 7.6 during the season.

TABLE 1. *Comparison of the results obtained from the different outdoor cultures*

Characters Checked	10 m^3 tank	14 m^3 tank	20 m^3 tank
Daily production ($10^6/m^3$) efficient	20·61	11·98	14·36
Total production (A) (dry weight Kg/-season/tank)	51.36	22.58	69.18
Total food supplied (B) (quantitites dry yeast Kg)	32.77	21.50	57.80
Conversion ratio (=A/B)	0.64	1.05	0.84

When the 14 m^3 rotifer cultures were considered, it was found that the highest rotifer density obtained was 330 individuals/ml and the daily production was 11.98×10^6 individuals/m^3. The total production on a dry weight basis was 22.58 kg/season/tank, while the total supplied dry yeast was 21.50 kg/season/tank. Therefore, the conversion ratio of rotifers in the 14 m^3 culture was 1.05. Also, the pH value ranged from 6.8 to 7.8.

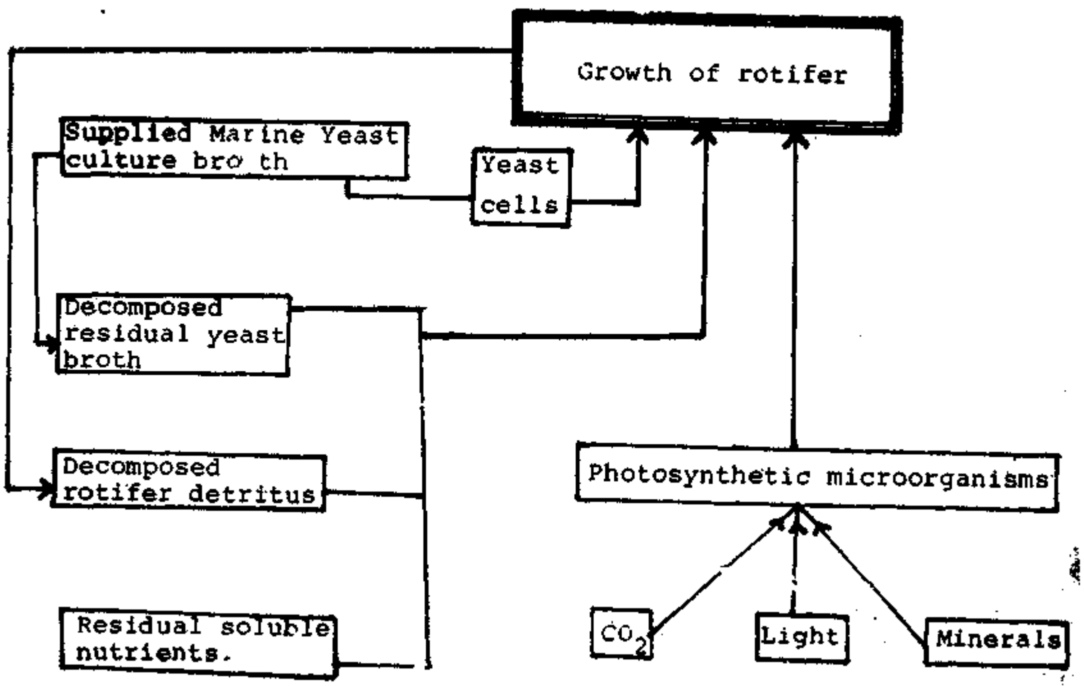
Finally, when the 20 m^3 rotifers culture was considered, it was found that the highest rotifer density was 340 individuals/ml, and the daily production was 14.38×10^6 individuals/m^3. The total production obtained was 69.18 kg/season/tank (on dry weight basis), and the total supplied dry yeasts was 57.8 kg/season/tank. Hence, the conversion ratio of the rotifers in the 20 m^3 culture was 0.84. During the culture period the pH value ranged from 6.8 to 7.6.

The results from the other two systems of rotifer culture obtained during 1977 and 1978 were compared with those from the outdoor culture system (Table 2). Results showed that the conversion ratio is best for the rotifers in the outdoor culture (0.84), while that of batch culture was the lowest (3.00). The conversion ratio of the rotifer continuous culture system showed an intermediate value (1.3). From Table 2, it is also clear that culture duration is lowest for the batch culture system (4 days), while it is upto 30 days for the continuous culture and up to 60 days for the outdoor culture. So, it is obvious that outdoor culture require less manpower activity than any of the other culture systems.

DISCUSSION

Mass culture of fish fingerlings and shrimp is the main aim of the mariculture activities at the Mariculture and Fisheries Department (Annonymous, 1979). Hence, the constant availability of suitable live food of high nutritional value and of suitable size to the fish larvae from the very early hatching stage is of great importance (May, 1970). Accordingly, high attention was directed towards the mass production of rotifers. The techniques of rotifer culture has been developed greatly specially in Japan where Hirata *et al.*, 1967 worked on high density rotifers culture. Furukawa *et al.*, 1973 has developed such rotifer culture technique to the large scale one, which is referred to here as the batch system culture by using marine yeast. Also, Al-Mattar *et al.*, (1979) has developed the continuous mass culture system. For rotifers culture, unicellular algae and baker's yeast was used for feeding, until (Kawano, 1968 ; Furkawa *et al.*, 1973) developed a new method of feeding, where marine yeast was applied instead of baker's yeast in the research conducted at the Association of Nobeoka Bay Fish Farm for Natural Protection. Kawano *et al.* (1977, 1978, 1979) then continued the application of this new method of feeding, and also developed the machanized system (where agitation heating and strong aeration are provided).

The outdoor culture system proved to have higher conversion ratio than that of the batch culture and the continuous culture systems (Table 2). This obtained high results of conversion ratio value could be attributed to the ecosystem of rotifers culture. It is thought that marine yeast which is supplied, is not utilized only as direct food to rotifers, but also, the yeast culture broth which contains a number of residual nutrients would serve as substrate for photosynthetic microorganisms happen to naturally localized in the rotifer culture water. It is believed that marine yeast starts and maintain the equilibrium of the ecosystem of rotifers culture which is believed to be as follows :



When the results of the outdoor culture system were compared in accordance with the three different types of culture tanks, it was found that : the 10 m^3 tank gave the highest culture density (Table 1), as well as the daily production and conversion ratio (0.64).

TABLE 2. *Relative productivity of each rotifer culture system*

Culture/system	Culture period	Conversion ratio	Supplied efficiency
Batch Culture ..	4 days	3.00*	42%
Continuous Culture..	30 days	1.3*	65%
Outdoor Culture ..	60 days	0.84	100%

* Al-Mattar *et al.*, 1979

It is important to notice that the 14 m^3 tanks are not provided with agitation system and also water depth is more high (1.5 m). The system lasts for only one to two weeks. From the results obtained from the 14 m^3 cultures and the 10 m^3 cultures, it is clear that agitation system, which allow for equal distribution of the supplied food and to prevent the accumulation of detritus, is of essential importance for rotifers culture.

On the other hand, when the rotifer culture is compared with accordance of culture volume, 10 m^3 and 20 m^3, it was found that the 10 m^3 culture volume gives higher density, daily production and conversion ratio.

As, the outdoor culture was compared to other rotifer culture systems, it was found that mass culture and production of rotifer is achieved with highest efficiency by applying the outdoor culture system. It allows for constant high production with minimum manpower.

The chemical composition of the cultured rotifer was analysed and results are given in Table 3. Also, the amino acid composition was analysed and checked and results are given in Table 4.

It is worth mentioning here that Watanabe (1978) has reported that marine fish larvae can't keep good health and good survival

TABLE 3. *The Chemical composition of cultured rotifer (outdoor culture system)*

Substance		g/100 g dry
Crude Protein (N × 6.25)	..	61.92
Crude fat (Soxhlet extract)	..	9.27
Crude Fiber	..	0.44
Crude Ash	..	16.34
Nitrogen-free extract	..	12.03

TABLE 4. *The Amino acid composition in Protein of rotifer*

Content		gm/100 gm protein
Arginine	..	5.25
Lysine	..	9.97
Histidine	..	1.35
Phenylalanine	..	6.20
Tyrosine	..	3.65
Leucine	..	6.75
Isoleucine	..	4.52
Methionine	..	1.21
Valine	..	5.09
Alanine	..	4.43
Glycine	..	2.70
Proline	..	3.85
Glutamic Acid	..	11.29
Serine	..	4.36
Threonine	..	3.67
Aspartic Acid	..	9.06
Tryptophan	..	1.00
Cystine	..	1.21

ratio if there is any deficiency of fatty acids in the diets. It is also noticed that rotifers have not sufficient essential fatty acids synthetic activities, but rotifer can accumulate in its body *Chlorella* cells which are rich in essential fatty acids content. This treating method could not be approached for rotifers supplied in large numbers, for space problem. However, another method was tried where rotifer could be fed on marine yeast already cultured in medium amended with essential fatty acids. By this indirect method rotifers containing essential fatty acids was cultured. It is now planned to enlarge such system in order to meet the increased demand of rotifer in the Department.

In the previous seasons rotifer was supplied in large numbers to the larvae of the following fish: *Epinephelus tauvina, E. areolatus, Acanthopagrus cuvieri, A. latus* and to the larvae of shrimp: *Matapenaeus affinis* and *Penaeus semisulcatus*.

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OBSERVATIONS ON THE ACCEPTABILITY OF ARTIFICIAL FEED BY THE FRY OF *MUGIL CEPHALUS* (LINNAEUS)

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ABSTRACT

A series of experiments were carried out to find out the acceptability of artificial feed by the fry of *Mugil cephalus* (Linnaeus) as compared to its normal feed—plankters. Experiments were conducted in glass jar and in plastic pool in freshwater. In one experiment, artificial feed used were (1) a mixture of ground nut oil cake and rice bran and (2) feed supplied by EWOS Aquaculture International Sweden (EWOS c 10). Average length and weight of the fry used in this experiment were 22 mm and 100 mg respectively. Best growth of fry was observed when they were fed with plankton. Percentage gained in weight was 96.7% in comparison with the initial weight. Among the artificial feed EOWS c 10 gave the better result (30.1%) than that of the mixture of groundnut oilcake and rice bran (0.1%). To find out the effect of cobalt and growth promoting hormone (Dianabol Methandienone, CIBA) in combination with the artificial feed, another set of experiment was conducted. Cobalt (as $CoCl_2$) and the hormone were added with the mixture of ground nut oil cake and rice bran @ 1.0 mg/kg of feed and 0.6 mg/g of body weight of fish respectively and the corresponding growth was observed to be 133% and 117%, gain in comparison with the initial weight.

After observing the preference of fry of *M. cephalus* for natural fresh feed namely plankters, another set of experiment was conducted with artificial feed and plankters together. In this experiment better growth was observed when the fry was fed with EWOS c 10 with plankton (percentage gain 466.5%) than that of mixture of ground nut oil cake and rice bran with plankton (331.5%) and only plankton (312.0%).

During this period of observations water temperature and its quality were regularly recorded. It was observed that the average values of temperature, dissolved oxygen, total alkalinity, pH and free carbon dioxide were 30.2°C, 4.0-5.3 ppm, 100.0-105.0 ppm, 7.2-7.3 and 4.4-4.4 ppm respectively.

INTRODUCTION

THE GREY MULLET *Mugil cephalus* (Linnaeus) forms an important constituent in polyculture practices in Israel, Hawaii and Taiwan. In India *M. cephalus* was introduced in fresh water fish culture after 1970 A.D. although it was an important item in coastal aquaculture over many decades.

The major problems hampering inclusion of *M. cephalus* in polyculture is lack of perfection in its mass propagation and inadequate knowledge on the food and feeding habits of the larvae and fry (Liao *et al.*, 1972 ; Kuo *et al.*, 1973 ; Nash *et al.*, 1973, 1974 ; Chaudhuri *et al.*, 1977). The problems impeding mass propagation of grey mullet has been reviewed by Nash and Kuo (1975). Its role in polyculture have been reported by Pruginin *et al.*, (1975) and Chaudhuri *et al.* (1975).

A series of experiments were conducted to find out the acceptability of artificial feed by the early and advanced fry of *M. cephalus* as compared to natural feed like plankters and also to a combination of both. The

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results of these experiments are reported in this communication.

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Material and Methods

Fry of *M. cephalus* were collected from Rishikulya Estuary (Ganjam Dist. Orissa, India). The experiments were conducted in cylindrical glass jars (10 l capacity) and in plastic pools (300 l capacity).

The jars were filled with 8 litres of aged tap water free from chlorine. In each jar five fry of *M. cephalus* conditioned earlier to different feed items and measuring 20-24 mm length and weighing 0.1 g on an average were introduced after bathing them in 10 ppm $KMnO_4$ to avoid fungal infection (Chaudhuri *et al.*, 1977). The feed tried were (i) ground nut oil cake and rice bran (GOC + RB) mixture in 1 : 1 ratio; (ii) formulated feed supplied by EWOS Aquaculture International Sweden (EWOS feed) and (iii) freshwater plankton consisting mainly of *Diaptomus* sp. and *Moina* sp. The feed items were supplied once a day @ 5% of body weight of the stocked fry. For each feed three replica were maintained.

In another series cobalt in the form of Cobalt chloride ($CoCl_2.6H_2O$ M.W. 237.9) @ 1 mg/kg of feed (GOC+RB) and growth promoting hormone Dianobol @ 0.6 mg/g weight of fry were added in combination with GOC+RB mixture. The jar experiments were continued for 15 days during which water temperature and important chemical qualities of water were analysed regularly on every fifth day by following the standard methods recommended by American Public Health Association 1965 for water and waste water analysis (*Am. Publ. Health. Assoc.*, New York, 12th Edn., 769 pp).

Yard experiments were conducted in plastic pools for a period of 30 days. Plastic pools were filled with aged tap water upto a height of 40 cm and the estimated average volume in each pool was 240 l. In each pool 4 advanced fry of *M. cephalus* of average weight of 0.2 g each were introduced. The feeds were supplied @ 10% of body weight of fry stocked and consisted of (i) freshwater plankton (ii) freshwater plankton and GOC+RB in 1 : 1 ratio and (iii) freshwater plankton and EWOS feed in 1 : 1 ratio. For each treatment two replicates were maintained. The composition of plankters supplied was dominated by *Moina* sp. and *Diaptomus* sp. Cobalt chloride was supplied @ 1 mg/kg of feed in all the cases.

Results

Glass jar experiments

The early fry were reared in jars for 15 days and were fed with (i) freshwater plankton (ii) GOC+RB in 1 : 1 ratio (iii) GOC+RB with growth hormone (iv) GOC+RB with cobalt chloride and (v) EWOS feed @ of 5% of the initial body weight (99.9 mg) once a day (Table 1).

Table 1. *Growth of fry after* 15 *days*

Treatments	Initial weight (mg)	Final weight (mg)	Percentage gain
Plankton ..	99.9	196.7	96.7
GOC+RB ..	99.9	100.1	0.1
GOC+RB+Growth Hormone (Methadienone)	99.9	113.3	13.3
GOC+RB+ $CoCl_2$ ..	99.9	217.1	117.1
EWOS Feed ..	99.9	130.0	30.1

Highest rate of growth (217.6 mg) was recorded by fry receiving GOC+RB along with cobalt chloride and the percentage gain in weight was 117.1. This was followed by the fry receiving plankton which recorded a growth of 196.7 mg and registered a percentage gain of 96.7.

Fry fed with GOC+RB and growth hormone showed slightly better growth (113.3 mg) and percentage gain (13.3) as compared to those fed with only GOC+RB mixture. The growth (100.1 mg) and percentage gain (0.1) was poorest in the latter case. The fry fed with EWOS feed grew to a size of 130 mg and percentage gain was 30.1.

Physicochemical conditions of water showed little variation in the course of the experiment (Table 2). The water temperature ranged from 28.5 to 31.0°C and pH varied from 7.0 to 7.4. Dissolved oxygen range was 3.1 to 6.2 ppm while that of free carbon dioxide was from 4.0 to 4.6 ppm. Total alkalinity varied from 100 to 110 ppm.

TABLE 2. *Water quality (Range and average of 6 observations)*

Treatment	Temperature (°C)		pH		Free CO_2 (ppm)		Total Alkalinity (ppm)		Dissolved Oxygen (ppm)	
	R	Av.	R	Av.	R	Av.	R	Av.	R	Av.
Plankton ..	28.5-31.0	30.2	7.2-7.4	7.3	4.0-4.6	4.4	100.0-110.0	105.0	4.7-5.8	5.1
GOC+RB ..	28.5-31.1	30.3	7.3-7.4	7.3	4.0-4.6	4.4	100.0-110.0	105.0	4.3-5.8	5.3
GOC+RB + Hormone ..	28.5-31.1	29.8	7.2-7.3	7.2	4.0-4.6	4.4	100.0-110.0	105.0	3.5-6.2	4.8
GOC+RB +$CoCl_2$	28.5-31.0	29.7	7.0-7.4	7.2	4.0-4.6	4.4	100.0-110.0	105.0	3.5-5.8	4.6
EWOS Feed ..	28.5-31.0	29.8	7.0-7.4	7.2	4.0-4.6	4.4	100.0-110.0	100.0	3.1-4.3	4.0

Plastic pool experiments

Based on the results of the glass jar experiments the following feed formulations were tried in 1 : 1 ratio (i) GOC+RB mixture and plankton (ii) EWOS feed and plankton, and (iii) the controls received only plankton. The advanced fry weighing on an average 0.2 g were fed @ 10% of body weight. Cobalt chloride was supplied @ 1 mg/kg of feed in all the cases.

Fry receiving the EWOS feed and plankton recorded the highest growth (933 mg) and the percentage gain in weight was 466.5 (Table 3). Fry fed with plankton alone reached an average weight of 624 mg and the percentage gain in weight was 312. Slight improvement in weight (663 mg) of fry was noticed when plankton and GOC+RB were supplied as feed and the percentage gain in weight was 331.5.

DISCUSSION

Many artificial diets compounded from both natural and synthesized materials have been tried on grey mullet larvae by Nash *et al.* (1973) with limited success. Pruginin *et al.* (1975) reported that grey mullets did not accept supplementary feed supplied in the form of Sorghum grains. Though pelleted feed was utilized to a certain extent, the fish did not grow faster. Chakrabarty *et al.* (1973) observed highest growth of carp spawn fed with zooplankters. In the present experiments it was noted that percentage gain in weight was more (96.7) when the early fry of *M. cephalus* were fed with plankton than the fry receiving EWOS feed (30.1%) and GOC+RB mixture (0.1%) (Table 1).

Nash *et al.* (1975) report that very little data is available on feeding of the larvae of mullets with artificial feed in combination with natural food organisms. In the present experiments lasting for 30 days when the advanced fry (200 mg) were fed with plankton alone a size of 624 mg (percentage gain 312) was reached and they recorded slightly better growth (663 mg) when they received plankton and GOC+RB in 1 : 1 ratio (Table 3). Growth was highest (933 mg) is case of fry supplied with EWOS feed and plankton in 1 : 1 ratio and the percentage gain was 466.5.

TABLE 3. *Growth of fry after* 30 *days*

Treatments	Initial weight (mg)	Final weight (mg)	Percentage gain
Plankton ..	200.0	624.0	312.0
Plankton+GOC+RB ..	200.0	663.0	331.5
Plankton EWOS Feed ..	200.0	933.0	466.5

Sukhoverkov (1967) showed in his experiment in carp production that addition of cobalt and vitamin to fodder positively increased growth and productivity. When fry of *Mugil parsia* (Hamilton) were fed with artificial feed in combination with 1 ppm cobalt chloride by Ghosh (1975), growth and survival rates of the fry increased. In the present experiments early fry of *M. cephalus* receiving GOC+RB and cobalt chloride recorded the highest growth of 217.1 mg and the precentage gain in weight was 117.1 (Table 1).

Adelman (1977) observed that when the yearlings of common carp were treated with bovine growth hormone @ 12.5, 25.5 and 100 mg/g per week at a temperature of 35°C, they responded with increasingly greater growth rates over fish receiving sham injections. In the present experiments when growth promoting hormone Dianobol @ 0.6 mg/g body weight of fry was administered in combination with GOC+RB mixtures at 29.5°C, the fry of *M. cephalus* showed a slightly better growth than those receiving GOC+RB mixture alone (Table 1).

The present observations clearly indicate that advanced fry of *M. cephalus* readily accept artificial feed when supplied along with natural food items comprised of freshwater plankters. They have recorded significantly better growth in the above feeding schedule. This study points to the possibility of raising large number of fingerlings of *M. cephalus* for composite fish culture in fresh water besides coastal aquaculture.

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OBSERVATIONS ON THE ACCLIMATISATION OF *DIAPTOMUS* SP. AND *MOINA* SP. TO SALINE WATER

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ABSTRACT

In the salinity range trace to 4.5 ppt, *Diaptomus* sp. (Copepoda) and *Moina* sp. (Cladocera) survived without any mortality for a period of more than 72 hours. At salinity range from 5.5 to 6.0 ppt no mortality occurred till 2 hours after which the plankters started dying gradually and only a few survived at the end of 6 hours. At the salinity range from 8.0 to 9.0 ppt, they started dying from the first hour itself and within two hours all died. And at salinity of above 9.25 ppt they died instantly.

By gradual acclimatisation the salinity tolerance of these freshwater plankters could be increased from 4.47 ppt to 5.26 ppt till 96 hours without any mortality. This also could be increased to 5.5 ppt with 25 per cent mortality till 120 hours and 5.8 ppt with 50 per cent mortality till 144 hours and with 75 per cent mortality till 168 hours.

INTRODUCTION

IN TAIWAN (Rabanal, 1967), Israel (Yashouv, 1972) and China saline water fish grey mullet *Mugil cephalus* (Linnaeus) played an important role in freshwater composite fish culture. Chaudhuri *et al.* (1975) stated about the feasibility of culture of *M. cephalus* together with the cultivated carps in Indian freshwater ponds. In an investigation about the acceptability of artificial feed by the fry of *M. cephalus*, Bhowmick *et al.* (1986) recorded better growth of these fry when they were provided with zooplankton mainly consisting of *Diaptomus* sp. (Copepoda) and *Moina* sp. (Cladocera) than the artificial feed. But these plankters died immediately in the saline medium and were not acceptable to fry. Chaudhuri *et al.* (1977) reported that fry reared in freshwater were found to be suffering from fungal attack. An understanding of the influence of salinity on freshwater plankton production is an essential prerequisite in rearing of grey mullet along with other species. Hence experiments were set up to see the salinity tolerance of these plankters and the possibility of their acclimatisation in saline water so as to provide feed and avoid fungal infection to the fry.

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MATERIAL AND METHODS

This experiment was conducted in cylindrical glass jars of 10 l capacity. These jars were filled with 8 l of sodium chloride solution of different concentration (Trace to 9.5 ppt at intervals of approx. 2 ppt). The evaporation loss was made up by adding distilled water every day in the morning.

For each salinity concentration three replica were maintained. Each jar was inocculatep with 0.2 ml of concentrated plankton consisting of *Diaptomus* sp. and *Moina* sp. Salinity was derived from chlorinity using the formula $S = 0.3 + (1.805 \times cl)$ (Strickland, 1968). As the total volume of water was small (8 l), only a small volume (250 ml) was collected from the different portion of the body of the water, mixed into representative sample and filtered through number 21 bolting silk (71 meshes per cm). The filtered water was again added to the respective jars. Numerical estimation was done by the drop method. Plankton samples were collected and estimated initially and subsequently at intervals of 1, 2, 3, 4, 5, 6, 16, 18, 20, 24, 48 and 72 hours. The estimated data is presented in Table 1. When this experiment was concluded, another experiment was set up in some cylindrical glass jar of 10 l capacity to see whether the salinity tolerance of these plankters can be enhanced by gradual acclimatisation to the higher salinity level. In this experiment also three replica were maintained. In the first experiment it was observed that there was no mortality of plankters during 72 hours at 4.47 ppt salinity level, hence in the second experiment the initial salinity was maintained at 4.47 ppt and it was gradually increased to 5.8 ppt during 144 hours. The plankton samples were estimated for every 24 hours till 192 hours. The estimated data are presented in Table 2. The salinity of each jar for both the experiment was checked regularly every day till the end of the experiment.

TABLE 1. *Survival of plankters after transfer from freshwater to various saline concentration*

Salinity (ppt)		Condition of plankters after											
Range	Average	1 hr.	2 hrs.	3 hrs.	4 hrs.	5 hrs.	6 hrs.	16 hrs.	18 hrs.	20 hrs.	24 hrs.	48 hrs.	72 hrs.
Trace—0.19	0.11	No Mortality											
2.00-2.50	2.30	No Mortality											
4.00-4.50	4.47	No Mortality											
5.50-6.00	5.80			25% Mortality	50% Mortality	75% Mortality	A few survival	All died	—	—	—	—	—
8.00-9.00	8.77	Few survival	All died	—	—	—	—	—	—	—	—	—	—
9.25-9.50	9.32	All died	—	—	—	—	—	—	—	—	—	—	—

TABLE 2. *Survival of plankters during acclimatisation from lower concentration to higher concentration*

Salinity (ppt)	Time hrs.	Condition of plankters
4.47	0	No mortality
4.90	24	No mortality
5.08	48	No mortality
5.26	72	No mortality
5.50	96	25 per cent mortality
5.80	120	50 per cent tymortali
5.80	144	75 per cent mortality
5.80	168	All died

RESULTS AND DISCUSSION

Ghosh (1979) observed in a laboratory trial that some diatoms (*Synedra, Navicula, Amphora,* etc.) grew well in lower salinities ranging from a trace to 8.0 ppt and with increase in salinity the growth of these species either decreased or they vanished completely to be replaced by some other species indicating that there is some optimal salinity range for individual species. Before releasing *M. cephalus* in freshwater pond Chakrabarty *et al.* (1976) reared the fry of *M. cephalus* in laboratory in saline medium and were provided zooplankton daily as food. During rearing they reduced the salinity level gradually by adding freshwater everyday, though neither the quantitative analysis of salinity nor the qualitative analysis of plankters were done. In the present study it was observed that at salinity ranging from trace to 4.50 ppt (average 4.47 ppt), there was no mortality of the plankters till 72 hours (Table 1).

But when the level of salinity was increased to 8 ppt the mortality started from the first hour itself and all of them died within two hours. They died instantly when the salinity level was more than 9.0 ppt.

As it was observed here that at an average salinity level of 4.47 ppt there was no mortality of plankton within 72 hours, it was decided to investigate the possibility of enhancing the salinity tolerance level of plankters by gradual acclimatisation. It was noted that by gradually increasing the salinity level from 4.47 ppt to 5.26 ppt there was no mortality within 96 hours (Table 2).

25 per cent mortality was recorded when the salinity was gradually increased to 5.5 ppt during 96-120 hours. After 120 hours the salinity level was raised to 5.8 ppt and it was observed that the rate of mortality increased to 50 per cent during 120-144 hours, 75 per cent during 144-168 hours and during 168-192 hours all died.

So from the above experiment it can be concluded that freshwater plankters *Diaptomus* sp. (Copepoda) and *Moina* sp. (Cladocera) can thrive well at 4.47 ppt salinity level and by gradual acclimatisation this level can be raised to 5.26 ppt without any mortality. Ghosh *et al.* (1973) reported that the fry of Indian major carp grew well in the salinity ranging 4.0 to 5.0 ppt. So the fry of Indian major carp can therefore be reared with the fry of grey mullet *M. cephalus* in brackishwater polycultural system.

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EXPERIMENTAL MASS CULTURE OF A TANAIDACEAN *APSEUDES CHILKENSIS* CHILTON AS A LIVE FOOD FOR AQUACULTURE

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ABSTRACT

The tanaidacean *Apseudes chilkensis*, a detritus feeder occupies an important position in benthic food chain of the Cochin Backwaters as it forms a highly preferred food organism for shrimps and fishes. Therefore, laboratory experiments have been conducted to elucidate the life-cycle, reproduction and growth of the species with the objective of evolving suitable culture methods to produce them inexpensively in sufficient numbers for use as live food in the culture of commercially important organisms.

Using filtered estuarine water and substratum of soft sediment enriched with artificial detritus, it has been possible to establish and maintain laboratory populations of this species. The animal grows under a wide range of temperature (25.5—33.0°C) and salinities (1 — 35‰) and proved to be a highly promising species for mass culture.

Post-marsupial growth studies revealed that the new born measuring 1.61 mm in length on average, undergoes 8-10 moults before attaining 5.5-6.5 mm to complete one generation time *i.e.* 22-25 days. Culture inoculated at the rate of 610 individuals/m^2 multiplied to 28000/m^2 in the course 45 to 50 days. Individuals were found to grow to a maximum of 10.3 mm in length in the course of 80-90 days. Occasionally mass mortalities occurred in the culture system due to the infestation of a microsporidean and ectocommensalic ciliates when unfiltered water was used.

INTRODUCTION

A REVIEW of the current literature on aquaculture reveals a realization among the concerned scientists on the need for research on live food organisms suitable for mass culture (Ivleva, 1969 ; Kinne, 1970 ; Omori, 1973). Besides the food value, the laboratory population of these organisms can act as effective tool in pollution studies and other ecological researches (Akesson, 1970 ; Bataglia, 1970 ; Reish, 1973). While selecting the forage organisms for aquaculture the prime consideration is its acceptability to the predator species as well as how easily and inexpensively it could be cultured. Experimental studies on two such species *Nitocra spinipes* Boeck and *Corophium triaenonyx* have been carried out in this laboratory (Anon., 1975; Gopalan, 1977). *Apseudes chilkensis* has been first reported from Chilka Lake (Chilton, 1924) and its occurrence in Kerala waters has been recorded by Barnard (1935). Pillai (1977) has pointed out the importance of tanaidacean in the macrobenthic community of Cochin Backwater. The role of tanaids in the benthic food chain of brackishwater is evident from their occurrence in the gut contents of fish and shrimp (Chilton, 1924 ; George, 1974).

The present paper conveys the results of experiments carried out to establish laboratory populations of *A. chilkensis* along with certain observations on its biology. Their growth rate in various salinities has also been assessed.

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MATERIAL AND METHODS

Samples of *A. chilkensis* along with other macrobenthos were collected from tidal mud flats of Cochin Backwater by gently sweeping the surface sediments (2 - 3 cm deep) with a drag net of 0.5 mm mesh size. The contents were carefully washed and transferred to plastic dish pans containing water and brought to the laboratory where berried females of *A. chilkensis* were sorted out for experiments. The cultures were set up in 40 litre circular polyethylene tanks having a diameter of 50 cm. The bottom of the container was layered with 3 cm thick sediments over a bed of 3 cm thick fine sand. Three types of substrata such as (A) surface sediment (B) subsurface sediment and (C) enriched subsurface sediment were tested. Organic matter content of the sediment was determined by the method suggested by El Wakeel and Riley (1957).

Dried mangrove foliage was ground, suspended in water in a trough and kept for 10 days agitating twice daily. The decomposing material filtered out and stored in refrigerator, was used for enrichment. Prior to the setting up of experiment, the sand and sediment were sieved (0.5 mm mesh), then heated up to 80°C and cooled to the laboratory temperature.

Filtered water was supplied in the tanks from a closed type of laboratory circulation system. Tanks were filled with water to a height of 20 cm and left as such for a day for settling. While replacing water and aerating, care was taken not to disturb the surface sediment. Salinity was maintained at $12 \pm 1‰$ during the experiment and the temperature fluctuated between 25.5—33.0°C. pH of the medium was maintained between 7-8 by the addition of lime prepared from oyster shells. In each tank 120 healthy berried females 6 to 8 mm size, were introduced. Two samples were taken at random from each tank at weekly intervals using a perspex corer of internal diameter 65 mm. The contents were siphoned out and seived (0.3 mm) in a finger bowl. After separating the animals, the sand and sediment were replaced in the area from where the core was taken. The animals were quickly counted and measured. Then the animals were also returned to the respective tank.

The growth of individuals of single brood in various salinities was studied by setting up 2 litre glass containers with substrate as mentioned above, using surface sediment alone. Desired salinities (1, 5, 10, 15, 20, 25, 30 and 35‰) were obtained by diluting the natural seawater or concentrating it by evaporation. One berried female was introduced into each container which was aerated; water was replaced once in a week. While transferring the animals to test salinities they were allowed to remain in intermediary grades in finger bowls for about 2 hours. Cultures were examined at morning and evening and exuvia cast on the surface were collected for measurement and examination of various growth stages. All cultures were run in duplicate for 28 days and average values were worked out. Cultures under salinities 10 ‰ and 15‰ were observed for longer time by supplementing the substratum with prepared detritus. Total length mentioned here is the distance between the anterior end of the carapace and posterior end of pleotelson.

RESULTS

As soon as the berried females were introduced into the culture tanks they began exploring and digging the substratum to bury themselves in the sediment. In 24 hours several tiny holes appeared at the bottom indicating the release of young ones from the marsupium. Gradually the number of such holes increased, making a densely pitted appearence all over the substratum. Several moults of varying sizes were seen cast on the surface. Individuals usually came out of the burrows prior to death and this facilitated their removal.

Growth of population

Density of population in the three cultures determined by weekly sampling has been expressed as number/m² in Fig. 1. In all cultures by attaining 28000/m² and thereafter it declined steeply (8000/m²) by the 11th week. Further progress was not observed in this culture.

Culture B did not show much progress after fourth week although a slight improvement could be seen (8400/m²) in the sixth week. The downward trend, thereafter reduced the population to 1200/m² by the eighth week. In culture 'C' a slight depression could be seen in the fifth week, but regained a strength of 14800/m² by the seventh week. This was followed by a fall in the density, 8800/m² in the 9th week but ascended further to 22000

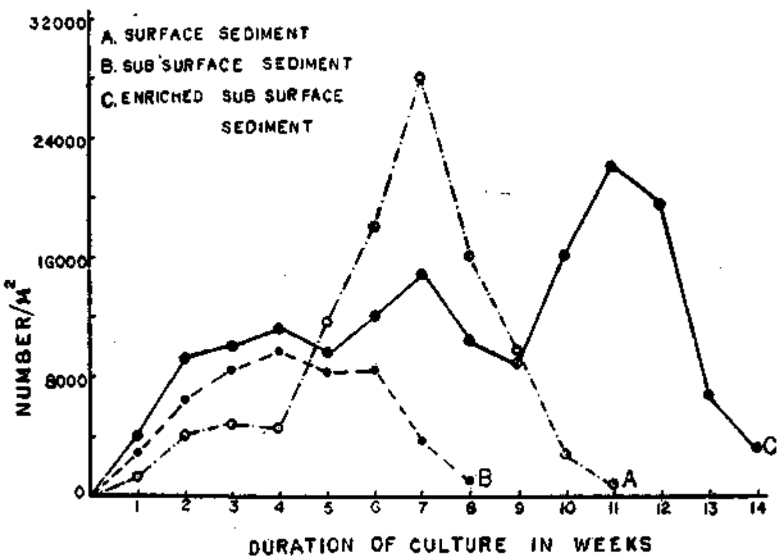

Fig. 1

a steady increase in the population can be seen in the initial stages as a result of the progressive release of young ones from the marsupium. This initial increase was recorded in the second week when culture 'C' showed a population of 9,200. In the third and fourth week, cultures B and C showed further progress while culture 'A' did not show much improvement ; moreover a few adults were seen dead in this tank. However, in fourth to seventh week population of culture 'A' showed a remarkable progress at the end of eleventh week and again descended to 3200/m² by the fourteenth week.

Growth of individuals

The whole series of post-marsupial development stages of *A. chilkensis* could be studied by rearing the broods obtained from isolated gravid females. The results of detailed investigation on the life history will be published elsewhere and only the effect of salinity on the growth rate of individuals is presented here.

Young ones newly released from the marsupium (manca I) measured on an average of 1.61 mm in length and reached the manca II (1.8 mm) stage in the course of 48 hours. Thereafter it became a juvenile when considerable variation in individual growth took place. The minimum size at first maturity (fully mature intra ovarian eggs) was attained at 5.16 mm after a series of moults (8-10). Most of the females of 6 mm size were found to carry embryos in their brood pouch. It took a minimum of 20 days in salinity 10‰ for the young ones to attain this condition (Table I). It was also observed that the broods maintained at salinities 15‰, 20‰ and 25‰ took 28, 30 and 27 days respectively to attain this length. Those reared in salinities 5‰ and 30‰ also reached this stage by about 30 days. In salinity 1‰ the young ones hardly reached 5 mm size by 30th day. Similarly growth was further retarded in salinity 35‰.

In cultures run for longer period the development from marsupium to death could be traced.

TABLE 1. *Growth of* Apseudes chilkensis *in various salinities (Growth in mm)*

Salinities (‰)	1st day	7th day	14th day	21st day	28th day	Mean growth per day
1	1.60	2.66	3.00	4.33	4.66	0.16
5	1.63	3.32	4.33	5.33	6.00	0.21
10	1.60	3.66	5.00	6.33	7.20	0.25
15	1.62	3.33	3.66	6.00	6.33	0.22
20	1.58	3.33	4.33	5.66	6.00	0.21
25	1.64	3.00	4.00	5.33	6.00	0.21
30	1.60	3.00	3.66	4.66	5.53	0.19
35	1.62	2.66	3.33	4.00	4.66	0.16

Discussion

Results of the experiments have revealed that tanaidacean *A. chilkensis* can easily be cultured on natural sediment, but the rate of multiplication and survival depends largely on the nutritional quality of the substrata. Since there is no previous information on culturing of this species it would be difficult to evaluate the present data on a comparative basis. Possibility for culturing ciliates, oligochaetes, cladocerans and harpacticoids on surface sediment has been proved by Spittler and Von Oertzen (1976). The highest density of population ($28,000/m^2$) was attained in 7 week on natural sediment with an organic matter content of 7.32%. The steep decline thereafter can be the result of fast impoverishment of growth promoting ingredients in the medium of culture A. Since culture C having an initial content of 6.58% of organic matter showed steady progress upto 11 week when supplemented with additional detritus at intervals, it can be deduced that the organic content of the detritus plays a major role in the survival and growth of population. The dwindling of the culture after the initial growth in culture B with 1.13% of organic matter can be attributed mainly to dietary deficiency.

Although culture C was supplemented with detritus at four weekly intervals, the growth curve showed a decline after 12th week. This implies that besides food there are other factors limiting the growth of population.

One such possible physical factor affecting the survival of this species is the consistency of the medium. The sediment surface which was initially more or less fluid in its physical consistency became compact and hardened by the passage of time and therefore, may have reduced the activity of benthic organisms (Vanderborght *et al.*, 1977).

The euryhaline nature of *A. chilkensis* is evident from their survival and growth under various salinity concentrations ranging from 1-35‰. As can be seen from Table 1 the fastest growth of 0.25 mm/day was obtained in salinity 10‰. The range of salinity between 5 and 25‰ seems to support reasonable growth 0.21-22.0 mm/day. This corroborated with our field data (unpublished) which showed that the highest density of *A. chilkensis* was recorded during the low saline period. Post marsupial development in salinity 10‰-15‰ revealed that the new born individuals measuring 1.6 mm in length undergo 8-10 moults to attain 5.5-6.5 mm size at which they get berried and release young ones, thus taking about 22-25 days to complete one generation time.

The development of some of the individuals in salinity 10‰ followed from marsupium to death showed that they attained 10.0 to 10.3 mm in the course of 80-90 days and produced 7-8 broods during the life span. The results of the present experiment indicate that *A. chilkensis* merits detailed investigation in view of aquacultural needs.

In the experimental conditions *A. chilkensis* was found to be free from the associated organisms. But in natural populations examined as well as in cultures maintained in unfiltered water large numbers were occasionally found infested with ectocommensalic ciliates such as *Zoothamnium rigidum*, *Lagenophrys cochinensis*, *Stentor coeruleus* and an endoparasitic sporozoan resembling *Nosema nelsoni*. Though seemingly harmless these associates may be potentially harmful to the hosts at times (Santhakumari and Gopalan, in press).

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OBSERVATIONS ON MASS CULTURE OF A EURYHALINE MACROSTOMIDAN TURBELLARIAN *MACROSTOMUM ORTHOSTYLUM* (M. BRAUN, 1885) IN RELATION TO REPRODUCTIVE BEHAVIOUR UNDER OPTIMUM SALINITY AND TEMPERATURES

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ABSTRACT

With a view to study the hatchability of the unreleased eggs of the Macrostomid Turbellarians collected from the Brackishwater Fish Farm at Kakinada, Andhra Pradesh, was killed by treating with absolute alcohol before desiccation. After 150 days of storage at room temprature, the dried material was soaked in various salinity media around 8‰. Hatching occurred after 15 days of soaking and detailed studies were made on their artificial culture in glass jars and in plastic pools. Initial cultural method for bacterivorous organisms involved use of ground nut oil cake extract and super phosphate.

Salinity tolerence studies indicated that the Turbellarians tolerated a wide range of salinity from 0 to 21‰, optimum range being 7 to 11‰, at water temperature between 27°C and 30°C. For mass culture, extracts of organic fertilisers prepared out of food grains, both dicot and monocot were tried. Among dicots, *Cicer artentinum* (Gram), *Dolichos biflorus* (Horse gram), *Lens esculenta* (Lenthils), *Vigna catjung* (Large white variety of beans), *Phaseolus mungo* (Black gram), *Arachis hypogoea* (ground nuts) and *Phaseolus aconitifolius* (' Matki ') extracts were experimented, and the extract of the last dicot gave the maximum productivity of organisms, followed by that of *A. hypogoea*. While the gram was tolerated despite low productivity, others proved to be totally unproductive. Among monocots, only *Triticum durum* (Wheat) was tried and it was next to *Arachis* in fertiliser activity. Further trials indicated that *T. durum* and *P. Ocontifolius* in equal proportions with addition of super phosphate (@ 0.2 mg/L of culture media) was the best combination yielding maximum productivity (1 million/m^3 culture media). It is very interesting to note that a brown variety of *Vigna sp.* gave the same maximum productivity as above.

Reproductive behaviour of the Turbellarians was studied under the optimum conditions of salinity and temperatures, and it was found to attain reproductive maturity by the 9th or 10th day. From this phase onwards, the individual gave rise to subitaneous eggs one at a time, at an interval of 24 hours. The egg which was uniformly dark with an egg membrane, hatch out within 24 hours, after being released and a maximum of 8 young ones morphologically similar as that of the adults could thus be produced. Hatchability of the above desiccated eggs was studied and it was observed that the eggs desiccated upto 5 days failed to hatch under optimum conditions. However, it was significant to note that the eggs obtained by rearing the animals in salinities at 12‰ and 15‰ and stored for 7 days at room temperatures hatched within 15-19 days. This indicated that resting eggs were produced under adverse conditions.

INTRODUCTION

DURING the qualitative studies, the zooplankton collected from pond No. 21 of the Brackishwater Fish Farm at Kakinada (Andhra Pradesh) in the middle of August, 1978, showed predominance of one kind of whitish organisms. On microscopic examination, some of these worm like organisms were egg bearing. A solitary egg was seen in the body of the individuals towards the tail portion. The egg was spherical with the prominent nuclear material in the centre. With a view to studying hatchability, the zooplankton comprising the egg bearing forms was killed by treating with absolute alcohol. After quickly draining the water the mass of zooplankton was dried in shade and was stored in plastic vials under normal room temperatures.

After 150 days of storage, the dried material was soaked in various salinity media around 8‰ being the same as that of the source pond. Hatching (Table 1) occurred after 15 days in the salinity media around 9‰. Initially only a few worms sticking to the interior wall of glass container were seen. These responded very favourably to the cultural method suitable for bacteriovorous filter feeding zooplankters (Shirgur, 1971, 1974; Shirgur and Naik, 1977; Naik and Shirgur, 1980 a, b, c.). This method involved administration of the supernatant liquid (S.N.L.) of the ground nut oil cake treated with distilled water and the phosphates in controlled dosages. The organisms started multiplying in 1 litre glass beakers, containing the seawater media around 9‰. Under the provision of unlimited live material, studies have been made at the prevailing water temperature range of 27° C to 30° C, on various aspects to understand the most optimum cultural factors which promote maximum fecundity of the organisms leading to successful mass culture. The principal objective also was to study the nature of resting eggs and thereby to understand the feasibility of their storage for initiation of the fresh cultures as desired. The various aspects under the present studies included: (1) preliminary details about reproductive behaviour (2) comparative efficiency of different organic fertilisers prepared out of mainly dicot and one monocot food grains under the combination of only one common inorganic fertiliser, $K_2H\ PO_4$ (Potassium phosphate dibasic) at the controlled dosage ranging from 0.05 to 0.2 mg/L of the cultural waters. In case of plastic pool cultures, super phosphate was used at the same dosage as the collective quantity required was high. In case of each fertiliser,

TABLE 1. *Particulars of hatching of the desiccated resting eggs of the macrotomid turbellarians in 1 litre beakers*

	1	2	3
Date of Collection ..	16/8/1978	13/7/1979	7/8/1979
Salinity media of collecition ..	Around 8‰, Pond No. 21 Brackishwater Fish Farm, Kakinada	(a) 12‰ (b) 15‰	5‰
Date of Desiccation ..	22/8/1978 (In plastic vials)	15/7/1979 (Upon Whitman Filter Papers)	9/8/1979 (Upon Cotton Sheets)
Date of Introduction of egg material (soaking)	(a) 2/12/1978, 4/12/1978 & 7/12/1978 (b) 12/1/79	21/7/1979 (Both media)	28/8/1979
Salinity media for hatching	9‰	9‰	9‰
Date of Hatching	27/1/1979	(a) 22/8/1979 (b) 27/8/1979	6/10/1979
No. of days for hatching	15	(a) 32 (b) 37	39
Duration of desiccation	150 Days	(a) 6 days (b) 6 days	19 days
Additional details	Salinity media of 8‰, 9‰, & 10‰ tried.	..	In the hatching media Rotifers first developed.

observations were made about maximum water solubility, comparative biological oxygen demand (BOD) and efficiency in promoting maximum fecundity of the cultural organisms. (3) Salinity tolerence studies ranging from freshwater to 35‰ under the effect of prevailing water temperatures and the most efficient fertiliser, viz., *Vigna* sp. (Brown variety of beans) and the equally suitable product out of *P. aconitifolius* + Wheat combination. (4) Reproductive behaviour of the organisms primarily under the optimum salinity media and further under the tolerating salinities ranging from freshwater to 21‰ within the temperature range as above and fertilisation involving administration of 7 mg/L *Vigna sp.* solution in combination with 0.1 mg/L of phosphates. The objective of these studies was to determine the average fecundity of the individuals under varying salinities.

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Material and Methods

For morphological studies, various narcotizers such as, Menthol, Magnesium Sulphate, Chloretone (Acetone Chloroform), Procaine Hydrochloride and Xylocaine were tried. These were tested singly and in mixtures. Of all, the mixture of 1% Procaine Hydrochloride and 2% Xylocaine proved satisfactory. The organisms transferred from the cultural beaker upon the clean slide with few drops of cultural media were narcotized by traces of the above mixture by a needle. After half an hour, the fully narcotized organism was fixed by treating with 0.25% Osmic acid. The temporary slides thus prepared were used for camera lucida drawings and micromorphometry.

For keeping the stock of the organisms, 1 litre (L) beakers were employed. In each of these glass pencil marks were made for the volume of 1 litre capacity for guidance to replace the evaporated water by addition of distilled water for maintaining the respective salinities of the media constant. The grades of salinity media were made by using the filtered seawater being circulated in the Institute and distilled water. Fertilisation of these beakers was done every 48 hours using only one ml of ground nut oil cake S.N.L. containing 12 mg of the solute, before the trial of other fertilisers. In combination the inorganic fertiliser (Potassium Phosphates) @ 0.1 ml/L was used. The bottom sediment was regularly being removed and examined for releasing of eggs. It was possible to maintain the cultural stock beakers continuously for the maximum duration of 6 months without changing the water media.

The first series of the experiments were carried out to understand the general features about reproductive behaviour of the organissms. In each of the experiments, at a time five test tubes of 30 ml capacity were used with 20 ml cultural media around 9‰. Later other salinity media were also tried. The media in the test tubes were fertilised at the usual rate and interval. From the stock beakers the subitaneous egg carrying individuals were isolated and the hatchlings obtained therefrom were used for introducing in the above test tubes taking one hatchling per test tube for various salinity media. Detailed observations were made during the course of the growth of the organism at pre-reproductive, reproductive and post-reproductive phases of the life-cycle. For pedigree studies mini test tubes of 4 ml capacity were also useful.

The second series of the experiments were undertaken to study the comparative efficiency of various fertilisers inclusive of ground nut oil cake.

In all, 9 fertilisers and two combinations were tried. For these experiments 1 L beakers were suitable. In each of the beakers of one set, respective S.N.L. at the rate of 1 ml/L was added. The drop in dissolved oxygen (D.O.) was determined by Winkler's method. For preparation of the supernatants of maximum concentration, 250 g of each fertiliser powder was treated with 1000 ml of the distilled water. After vigorous stirring the residue on thorough soaking in the water, was allowed to settle. The clear supernatant liquids were collected in the bottles after nearly 5 hours and were preserved in the refrigerator for trials. By weight method, the values of solutes at maximum solubility levels were determined. The values of the comparative efficiency as reflected by the average fecundity of the individual organism are worked out. For determination of these values 30 ml test tubes were suitable. In each of these, 20 ml cultural media of the common and the optimum salinity of 9‰ were taken. The fecundity of the individuals was determined under the administration of different fertilisers by summing up the total number of the young ones produced at the end of the whole life of an individual during the reproductive phase. The parents were carefully transferred to new pre-fertilised test tubes to continue the normal activity. During these experiments only subitaneous eggs were generated being the optimum salinity media and the counting of the young ones was not delayed. In the cultural test tubes the fertilisation was done once in 48 hours. In case of the S.N.L. of the *Vigna* sp. four times dilution was done so as to administer @ 7 mg/L as the solubility and BOD were the maximum.

The third series of the experiments were concerned with determination of salinity range in which the organisms survive. For these studies freshwater and various grades of seawater were tried. The seawater grades from 1 to 35 ppt salinities were tried, in 30 ml test tubes using only 20 ml media. In each of the media, pre-fertilised, 10 adults from the stock beakers of 9‰ media were introduced. Fertilisation was done every 48 hours using *Vigna* sp. S.N.L. and Potassium phosphates at the usual dosages. Observations were made continuously and the survival periods are noted.

In the fourth series of the experiments, under the optimum conditions of fertilisation, the objective was to determine the comparative average fecundity in various grades of salinity media in which the organisms continuously survive. The data is collected on hatching from both subitaneous and resting eggs produced by the individuals in whole life. The sequence of production of both the kind of eggs and the number of hatchlings produced were also noted down. Resting eggs which were not hatching in the most adverse salinity grades are taken into account for summing up of fecundity values due to the reason that such resting eggs could hatch in the optimum salinity media if provided. The methodology was same as in case of determination of fecundity values in relation to comparative efficiencies of different fertilisers. Comparative fecundity is thus the most important criterion to determine the most efficient fertiliser and the salinity media.

As regards hatchability of the desiccated eggs, the first series of the experiments were concerned with subitaneous eggs. These were collected on microscope slides on which desiccation was very quick. These were taken up for hatching in the optimum salinity media but such eggs desiccated for 5 to 15 days failed to hatch. These eggs for desiccation were collected from surface of the cultural beakers and test tubes of para-optimal (11‰ to 10‰ and 8‰ to 7‰) and non-optimal salinity media. The peculiar shape and structure of the resting eggs keeps them buoyant in the upper columns of the cultural media. The resting eggs were collected upon cotton sheets and Whitman filter papers by straining the surface waters by decantation. On complete desiccation under room temperatures, the cotton sheets and the filter papers were carefully folded and kept wraped up in the ordinary clean paper under natural room temperature for future use. It is necessary to preserve these in insect-proof containers.

The cultures at the beaker level were extended to plastic pool level. The optimal culture media of 500 and 400 L were taken in the pools of dimensions of 60 cm X 120 cm and 90 cm × 90 cm respectively. Population densities per L at the peak level was determined. The rate of fertilisation was needed to be doubled @ 14 mg/L of *Vigna* sp., S.N.L. per 48 hours as the conditions of BOD level was quite variant from those of beakers. Super phosphate was used @ 0.2 mg/l in one of the pools. In the other combination of *P. aconitifolius* + wheat and Pot. Phosphate was tried with equal efficiency.

Observations

The Turbellarians under the current studies bear morphologically a close resemblance to Gastrotrichs especially of *Hemidasys* group. However on careful studies the identity becomes clear. On initial taxonomic observations the organisms were placed under Order Macrostomida, Class Turbellaria under the Phylum Platyhelminthes. The general body length varies in the range of 0.55 to 0.6 mm. The detailed studies are in progress for identification upto species level.

The dried material stored in plastic vials and kept for nearly 150 days under the room temperatures had been subjected to soaking and subsequently for hatching in various salinity media around 8‰, same as the source pond. However hatching occurred only in salinity grades around 9‰. This indicated the most optimum salinity even before the detailed studies were made on salinity tolerence.

The morphological features have been shown in Fig. 1. The animal is long almost with parallel longitudinal body contours. It is dorsoventrally flattened with rounded head end. At 1/10th distance from the tip of the head, a pair of ocelli are distinct. The tail portion looks 'lobed fin' like used by the animal to anchor to a hard substratum with the help of adhesive papillae and the animal detaches the anterior portion for probing. The organisms measure 0.55 to 0.6 mm in body length. These are capable of crawling on the interior glass walls of the containers and remain suspended too with undulating movements in the water columns. Under microscope in between the ocelli a gut portion is visible. Under the narcotized state the animal is in passive movement with distinct ciliation visible along the body contour. The matured animals bear a solitary egg near the rear portion of the body delimited by the junction of tail lobe. The subitaneous egg measures 0.061 in diameter being almost similar to that of resting egg. The animal is seen sloughing as growth proceeds and the integument is pigmented.

Preliminary observations on general features of reproductive behaviour are given below.

Range of water temperatures for experiments: 27° C - 30° C.

Morphology of the reproductive stages: (*a*) Generally only one morphological stage :observed. The basic character is reproductive uni-morphism. These organisms reach the body size of 0.5 mm in size within 8 days of being hatched out. The young ones after being hatched resemble the adults morphologically. The reproductive unimorphic stage is illustrated in Fig. 1 a. (*b*) In non-optimum (adverse) salinities, a few heteromorphic forms appear. The body length is reduced to 0.3 mm and a mid-dorsal extension of the body (a flap like projection) develops. This is suggestive of spermatopositing for forms pre-fertilization of the ova emerging as the resting eggs.

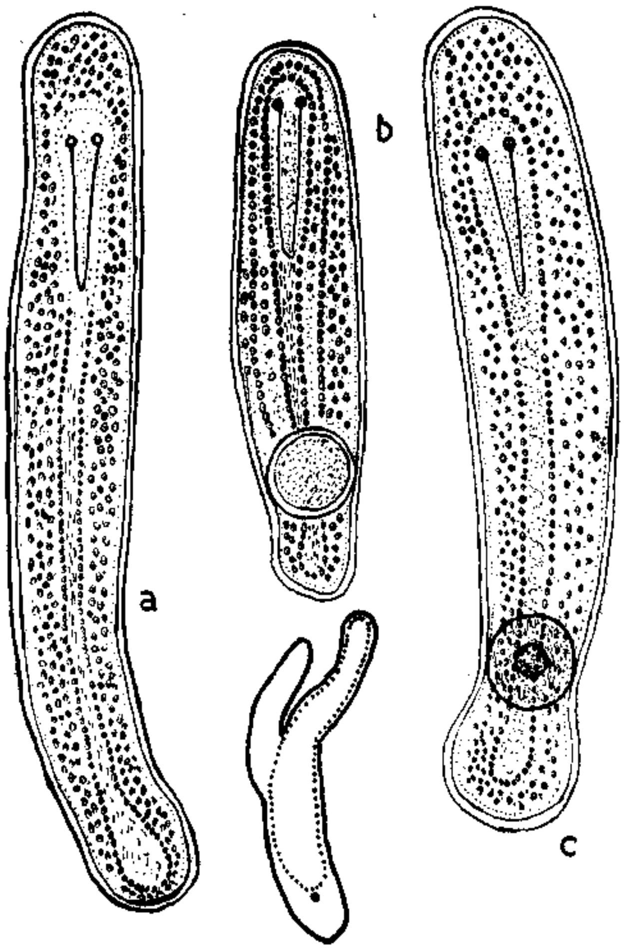

FIG. 1. Macrostomidan turbellarian *Macrostomum orthostylum*: a. a fully stretched specimen (body length 0.5124 mm); b. a specimen bearing a subitaneous egg (body length 0.4636 mm and egg diameter 0.0610 mm) and c. a specimen bearing a resting egg (body length 0.5856 mm and egg diameter 0.0621 mm).

Pre-reproductive phase: The duration is of 8 days. On 9th day, at the pre-tail portion of the body a subitaneous egg is ready for release within 6 hours of such formation.

Subitaneous eggs : (*a*) These are uniformly dark (Fig. 1 b). Within 24-26 hours after release, the egg hatches out into 4-8 young ones. (*b*) In a sequence of egg laying activity in all salinities of survival, first and second and following ones comprise solitary eggs depending upon the degree of adversity of salinity. The hatchlings numbering 4, 6 and 8 are produced respectively.

Resting eggs : (*a*) Unlike the subitaneous eggs, these are disc shaped with nuclear material concentrated in the middle (Fig. 1 c). The surrounding portion seems to be vacuolous. Due to this characteristic, the eggs are buoyant in upper layers of the cultural waters. The egg membrane is yellowish-brown and is tough as well as horny. (*b*) The resting eggs are not found in the optimal salinity around 9‰. (*c*) These eggs are produced in all the para-optimal and no-optimal salinity media. Sequentially in relation to subitaneous eggs, these are formed serially during the middle phase of reproductive life. These are preceded and succeeded by a few or more number of temporary eggs (one egg-one batch). (*d*) The resting eggs on passing out remain glued to the integument and these are sloughed out in batches of 2-3 at a time. (*e*) A resting egg gives rise to only one individual unlike the subitaneous ones. (*f*) The resting eggs are seen to be produced by parthenogenesis mostly in paraoptimal salinities. In these adverse media occurrence of heteromorphic individuals as described above is suggestive of pre-fertilization of the ova destined to be resting eggs. (*g*) The resting eggs from para-optimal salinities take nearly 8 days for being hatched in respective media. These eggs in non-optimal salinity media in the range of 6‰ to 5‰ and 12‰ to 15‰ however are delayed in hatching in respective media, the duration being 18-25 days.

Asexual reproduction : Unlike two families of order Rhabdocoela, asexual reproduction was not observed in this species. This mode of reproduction involves formation of new individuals by transverse fission.

In the second series of experiments (Table 2), 9 fertiliser solutions and two combinations were tried to understand comparative efficiency of these as reflected by respective average fecundity values of the animals tested. From the above Table it can be seen that *Vigna sp.* with maximum solubility @ 28.0 g/L and maximum BOD value, has proved to be the best and the fecundity is the maximum. On an average 108 progeny/individual were produced during the whole life periods. Similar results were achieved by using *P. aconitifolius*+Wheat mixture solution. This was followed by Ground nut oil cake+wheat mixture solution with 90% proliferation. Further, *P. aconitifolius*, ground nut and wheat solutions gave proliferation of 85%, 80% and 60% of the maximum fecundity value respectively. In *P. mungo* solution, survival of the species was for only 72 hours. In the rest of the fertiliser solution-media, the organisms did not survive. In regard to drop in dissolved oxygen, *Vigna* sp. showed maximum followed by others with the drop of 2.0, 1.75 and 1.25 and 1.0 ppm, thereby giving fermentation indices. However these indices seem to be of no consequence in relation to generation of suitable forage bacteria which alone ensure survival and multiplication of the cultural organisms. From these observations it seems that the bacterial flora is qualitatively suitable as developed in *P. aconitifolius, Vigna* sp., ground nut and wheat fertilisation. In case of ground nut, the forage bacteria that normally develops is identified as *Pseudomonas acriginosa* (Shirgur and Naik, 1977). It would therefore be very interesting to understand such flora comparatively in regard to other suitable fertilisation.

TABLE 2. *Comparative efficiency of various organic fertilisers in relation to fecundity and BOD values for culture of macrostomid turbellarians*

(*General features* : 1. For these experiments only 9‰ media were tried, being the optimum salinity.

2. Only one ml of the concentrated supernatant solution of each fertiliser was used per 1 litre beaker.

3. In each of the 1 litre beakers 10 non-egg bearing matured specimens were introduced after 24 hours of fertilizer activity, for osbervation of survival and proliferation.

4. Fecundity studies were made in 30 ml test tubes with 20 ml media)

Fertiliser used	Maximum water solubility (g./L of solute)	Fermentation Index (Drop in D.O., ppm)	Fecundity	% of Fecundity
Vigna sp. (Brown beans) ..	28.0	3.0	108	100
P. aconitifolius+*Triticum durum* ('Matki'+wheat) ..	6.0	2.0	108	100
Arachis hypogoea (Ground Nut Oil Cake) ..	12.0	2.0	87	80
Triticum durum (Wheat) ..	8.0	2.0	65	60
Phaseolus mungo (Black Gram) ..	8.0	2.0	Only 72 hours survival.	
T. durum+*Arachis hypogoea* (Wheat+Ground Nut) ..	10.0	1.75	97	90
Phaseolus aconitifolius ('Matki') ..	4.0	1.75	92	85
Lens esculenta (Lentils) ..	8.0	1.25	Not survived.	
Vigna catjung (Large white beans) ..	4.0	1.0	Not survived	
Dolichos biflorus (Horse Gram) ..	7.0	1.0	Not survived.	
Cicer arientinum (Gram) ..	25.0	1.0	Not survived.	

By the third series of the experiments salinity tolerance studies were carried out (Table 3). It was revealed that under the prevailing water temperature range of 27°C to 30°C, 9‰ was the most optimum. It was corroborated by other studies also, especially the highest rate of fecundity value. It can be seen that the organisms are quite capable of tolerating a wide range of salinities from freshwater to 21‰. The para-optimal salinity has been ranging from 7‰ to 11‰ at either levels of the scale, the 9‰ being the mean. In these salinities multiplication of the organisms is the fastest. In other grades below 8‰ and above 11‰ also the organisms thrive. These salinities are non optimal with comparatively less efficiency of proliferation.

In the fourth series of the experiments, rate of proliferation was studied using all the surviving salinity media from freshwater upto 21‰. In all these media the best fertiliser solution from *Vigna sp* was used. The results are summerised in Table 5. It can be seen that in 9‰ media, fecundity is the highest followed by 7‰+8‰+10‰ to 11‰, 1‰ to 6‰+12‰ to 15‰, and Freshwater +16‰ to 21‰ salinity ranges. The rate of proliferation in terms of fecundity is thus highest in 9‰ proving to be the best medium for culture under *Vigna sp.* fertilisation.

TABLE 3. *Survival periods of macrostomid turbellarians in varying salinity grades*

(*General features*: 1. Range of Water temperatures: 27°C—30°C.
2. Salinity of the seawater from Institutional circulation: 34‰.
3. 24 hours pre-fertilised salinity media of 20 ml in each of the 30 ml test tubes were used for introduction of the 10 non-egg bearing matured specimens)

Salinity (ppt)	Survival periods	Proliferation suitability
Freshwater	Continue to survive.	Proliferation after 10 days.
1	,, ,,	,, ,,
2	,, ,,	8 days, thereafter.
3	,, ,,	,, ,,
4	,, ,,	,, ,,
5	,, ,,	After 6 days
6	,, ,,	Proliferation activity starts after 72 hours
7	,, ,,	,, ,,
8	,, ,,	,, ,,
9	,, ,,	,, ,,
10	,, ,,	,, ,,
11	,, ,,	Proliferation after 6 days
12	,, ,,	,, ,,
13	,, ,,	,, ,,
14	,, ,,	Proliferation after 8 days
15	,, ,,	,, ,,
16	,, ,,	Proliferation after 10 days
17	,, ,,	,, ,,
18	,, ,,	,, ,,
19	,, ,,	Proliferation at slow rate and the populations thin.
20	,, ,,	,,
21	,, ,,	,,
22	8 Days	..
23	6 Days	..
24	96 Hours	..
25	10 Hours	..
26	5 Hours	..
27—34	Mortality within 3 hours	

TABLE 4. *Comparative average fecundity values based on pedigree studies of the individuals of macrostomid turbellarians in the cultural media from freshwater to 21‰ and egg laying sequences*

(*General features*: 1. On an average there are 15 batches of egglaying with a single egg at a time.
2. The Resting eggs below 5‰ and above 15‰ adverse salinity media did not hatch out.
3. Temperature range—27°C—30°C.
4. 20 ml media of each salinity were taken in 30 ml test tubes for expts)

	1	2	3	4
Salinity tested (ppt) ..	1 to 6 and 12 to 15	7 to 8 and 10 to 11	9	Freshwater and 16 to 21
Subitaneous eggs (%)	60	80	100	50
Sequential batch (Nos)	1 to 5 and 12 to 15	1 to 6 and 10 to 15	1 to 15	1 to 3 and 12 to 15
Resting eggs (%)	40	20	..	50
Sequential batch (Nos.)	6 to 11	7 to 9	..	4 to 11
Average No. of hatchlings for whole life (Fecundity)	66	87	108	52

Table 1 shows the details of hatching of the desiccated resting eggs. The results of these few experiments tend to show that the resting eggs out of para optimal grades of salinity hatch out within 15 days whereas those out of extreme salinities take 32 to 39 days even when subjected to hatching in optimum salinities.

Review of the literature on culture of the macrostomid turbellarians showed that a few species have been cultured under laboratory conditions using mainly the wheat infusion comprising ciliate protozoans (Needham *et al*, 1959 ; Kinne, 1977). The reproductive behaviour of the present species exhibits several peculiarities. Asexual mode of reproduction by transverse fission has not been noticed unlike two rhabodcoelid families, Ctenulidae and Microstomidae (Hyman, 1951 ; Giese and Pearse, 1974). In the species under study the mode of reproduction is by production of subitaneous eggs invariably at the beginning of the reproductive phase of the animal at all the surviving salinities, followed by generation of resting eggs in succession the number of batches being predetermined in relation to degree of environmental adversity mainly in terms of salinities. In the salinity media where the successive production of resting eggs is high, the organisms with a peculiar mid-dorsal flap (Fig. 1) were discovered. These closely resemble the forms described in case of Acoelid species (Kinne, 1977). The mid-dorsal flap develops due to catapulting of copulatory organs preparatory for copulation. Occurrence of such forms in the cultural populations show that the species is hermaphrodite and the resting are also produced by pre-fertilisation of the ova.

In case of the subitaneous eggs, these dried for 7 days and upto 14 days failed to hatch showing that those are meant for only wet hatching.

The plastic pool results have indicated that under their specific conditions, fertilisation dosage needs to be doubled, possibly due to higher rate of bio-degradation of the fertilisers administered and the larger surface area exposed to the air. Productivity of 1 million/m^3 of culture media was achieved. It has been observed that slight increase in phosphate fertilisation results in appearance of unwanted brown algae, ***Microcera*** **sp.** In case of cultures in the glass beakers, the blue green algae, ***Oscillatoria*** **sp.** becomes a nuisance in the salinity media of 5‰-7‰ being the maximum followed by other media upto 15‰. Due to this reason, keeping the cultural beakers within the brown cartons under the muffled state gives better results. *Nitzschia* sp. is another alga belonging to Bacillariophycae which forms brown encrustations upon the interior walls of the cultural beakers. This alga however is comparatively less deleterious than *Oscillatoria* sp.

Discussions and Conclusions

The successful culture of the macrostomid turbellarians in the glass beakers at laboratory level and in the plastic pools underscores the importance and consistency of the cultural method. The first report of similar method (Shirgur, 1971) was concerned with culture of freshwater Rotifers, and Daphnids (*Moina sp.*) at laboratory level and applied to nursery ponds of the fish seed farms under the field conditions. The method involved use of Ground Nut Oil Cake as a principal fertiliser in combination with very low proportion of cattle dung and super phosphates, for administration at the regular intervals of 24 to 48 hours depending upon the quantity of the above zooplankters in the known volume of the cultural media. A brief note (Shirgur, 1974) had been circulated to all the fishery workers highlighting the importance of this method known as the 'Phased Fertilisation Method'. Now this has become the widely accepted method all over the country for production of fish seed in freshwater fish farms (Shirgur, 1974). By this method the desirable quality of the zooplankton develops rapidly within 48-72 hours after administration of the above fertiliser combination, unlike the previous method using only the cattle dung, which was effective after 10-20 days for appearance of zooplankton in succession to the bloom of phytoplankton (Shirgur, 1971, 1974). In the phased fertilisation method primary productivity is bypassed by introduction of the readily utilisable substitutes comprising mainly the food grain products rich in organic substances. By this short cut, food chain is initiated by aerobic bacteria (especially of *Pseudomonas* group) which multiply at fastest rate by breaking down the organic fertilisers synergised by phosphates. These bacteria constitute the principal food of the culturable zooplankters comprising rotifers, daphnids (*e.g. Moina* sp.) and others, with a common characteristic of filter feeding habit. Under the observations, on administration of the fertilisers the cultural media become cloudy due to large scale production of bacteria. On introduction of the filter feeders the fertilised water as above assumes crystal clarity indicating that the bacteria are readily utilised. This has been observed in case of the rhabdocoelid turbellarians too.

It is significant to reveal that phased fertilisation technique at the sophisticated level has become applicable to brackishwater zooplankters comprising the euryhaline cladocerans (Shirgur and Naik, 1977; Naik and Shirgur, 1980, a, b and c). In this work, ground nut oil cake has been tried in comparison with urea and phosphates showing thereby that the oil-cake phosphate proved to be the best and the fertiliser solution (supernatant liquid) was used for phased fertilisation every 48 hours @ 12 mg./L of the cultural waters, in case of the above euryhaline species of cladocera, *Alona taraporevalae* Shirgur and Naik.

In the present work, the organisms belonging to diverse taxonomic group of Macrostomida (Class : Turbellaria, Phylum : Platyhelminthes) have also readily responded to the same fertilisation method. Eight dicot food grains (belonging to Leguminosae) and 1 monocot food grain (wheat) were tried for comparative efficiency as reflected by comparative fecundity. In these studies, *Vigna sp* and mixture in equal proportion of wheat+*P. aconitifolius* have proved to be the most efficient followed by *P. aconitifolius* and ground nut oil cake under the optimal salinity media of 9‰.

Salinity tolerance studies have indicated that the organisms were euryhaline in nature tolerating a wide range from freshwater to 21‰, the optimum occurring at 9‰.

Detailed observations have been made on conditions especially of the adverse nature in terms of non-optimal salinities. This information is very important in that resting eggs can be collected and stored in dry condition under normal room temperatures for a number of days for utilising in initiation of cultural work as desired. So far, maximum duration of storage has been 150 days.

From the above results it can be concluded that the sophisticated method of phased fertilisation operates with equal efficiency in both freshwater and saline media and diverse group of the organisms are so far cultured. Further studies are in progress on two species of euryhaline copepods the cultures of which are maintained by the above method with equal feasibility. In regard to the species under the current studies, for optimal conditions, *Vigna* sp. and mixture in equal proportions of *P. aconitifolius+wheat* @ 7 mg and 6 mg/L respectively would be the best organic fertilisers in combination with phosphates preferably Potassium phosphates @ 0.05—0.2 mg/L rate, yielding maximum productivity at 9‰ media under the laboratory conditions. The results in plastic pools have shown that the quantum of fertilisation needs to be doubled in case of organic component keeping the inorganic at the same level as above. The latter in slightly more dosages are observed to promote the growth of unwanted brown algae, *Microcera* sp. which forms the bulk of the bottom settled matter. In the plastic pools the productivity of 1 million/m³ cultural media could thus be achieved at peak level. Application of phased fertilisation method to Brackishwater and marine farms which are being currently promoted would thus help to achieve desirable results, especially at the nursery level rearing of suitable varieties of economically important prawns and fishes.

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Proc. Symp. Coastal Aquaculture, 1986, 4 : 1261-1266

OBSERVATIONS ON THE FEEDING AND MOULTING OF LABORATORY REARED PHYLLOSOMA LARVAE OF THE SPINY LOBSTER *PANULIRUS HOMARUS* (LINNAEUS) UNDER DIFFERENT LIGHT REGIMES

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ABSTRACT

Phyllosoma larvae of the spiny lobster *Panulirus homarus* hatched under laboratory conditions were fed on 1-2 day old *Artemia salina* nauplii. The feeding intensity and moulting frequency of the larvae were studied. When fed with one day old *Artemia* nauplii, the phyllosoma larvae consumed at an average rate of 15.1 ± 0.94 nauplii/day and moulted five times in 31.2 days to reach the IV phyllosoma stage. But those fed with two day old nauplii consumed 19.3 ± 1.6 nauplii/day and required 34 days to complete the fifth moult under similar environmental conditions.

Studies on the effect of light on the feeding and moulting of phyllosoma larvae indicated that consumption of *Artemia* nauplii was significantly higher in natural day-light periodicity, (15.1 ± 0.94 nauplii/day) than in 24 hr darkness (11.1 ± 0.57 nauplii/day) and 24 hr light (12.2 ± 0.45 nauplii/day). The reduced food consumption in the groups exposed to 24 hr dark and 24 hr light was reflected in the moulting frequency also. The phyllosoma completed the fifth moult in 31.2 days under natural day-light periodicity, while it required 37 days under 24 hr darkness and 35.5 days under 24 hr light.

INTRODUCTION

PHYLLOSOMA LARVAE of *Panulirus homarus* are positively phototactic and swim towards natural and artificial sources of light. Segal (1970) summarised the effect of varying photoperiods on marine invertebrates. But information on the effects of photoperiodism on feeding in crustacean larvae is limited (Templeman, 1936 ; Huntsman, 1923).

Since the phyllosoma larvae are selective feeders, nutritionally rich and suitable sized prey should be identified and supplied to ensure maximum survival and growth rates. This view has been stressed by earlier workers also (Saisho, 1966 ; Dexter, 1972 ; Wickins, 1972). Though early larval stages of *Panulirus inflatus* (Johnson and Knight, 1966) and *Panulirus longipes* (Saisho and Nakahara, 1960) were successfully fed on *Artemia* nauplii, the food consumption and growth in relation to size and nutritive aspects of the prey was not properly understood. The present study is on the effect of different photoperiods on feeding, moulting frequency and survival of phyllosoma larvae of *Panulirus homarus* and the larval feeding on two different sizes of *Artemia salina* nauplii.

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preparation of the manuscript. Thanks are also due to the staff of Kovalam Field Centre of Central Marine Fisheries Research Institute for their help in carrying out the work.

Material and Methods

An ovigerous female of *Panulirus homarus* (Linnaeus) released phyllosoma larvae in the field laboratory at Kovalam during February, 1979. The larvae were transferred to plastic tanks of 45 l capacity with fresh filtered sea water and fed freshly hatched *Artemia salina* nauplii. On the second day after hatching, the healthy larvae were divided into four series, each series having five groups of three larvae each. Two of the four series were exposed to natural day-night cycle (approximately 12 hr L : 12 hr D). Of the other two series, one was exposed to 24 hr darkness. The containers with the larvae were kept in a black wooden box and were exposed to light for 10 minutes everyday while changing the water and feeding. The fourth series of larvae were exposed to 24 hr light by using 40W flourescent lamp fixed 4 feet above the containers.

The larvae were reared in transparent plastic containers (150 ml capacity) with 100 ml of filtered (using 1μ filter) fresh seawater. The salinity of the water ranged from 32 to 34.5‰ and the temperature in rearing containers varied from 25.4 to 30.0°C with a mean of 28.1°C. The water was changed daily.

Of the two series exposed to natural day-night cycle, one was fed on freshly hatched *Artemia salina* nauplii and the other with second day *Artemia* nauplii. The groups exposed to 24 hr L and 24 hr D were fed on freshly hatched nauplii. In each container 125 nauplii were released daily at 1000 hrs after removing the unfed nauplii supplied on the previous day.

The containers were checked daily for exuviae and dead larvae, and the condition of each larva and the date of moulting was recorded. Since the length of the living larvae could not be measured accurately after each moult, the moulting frequency was considered as an index of growth. The experiment was conducted for 40 days.

Results and Discussion

The phyllosoma larvae exhibited a higher feeding activity almost alternating with a lower feeding on the subsequent day in all the tested photoperiods (Fig. 1, 2). Average daily consumption of fresh and second day *Artemia* nauplii increased with age of the larvae under natural day-night conditions. Feeding rate increased from 9 nauplii/day on the first day of the experiment to a peak of 31 nauplii on 27th day when fed with freshly hatched nauplii and the consumption increased from 8 nauplii/day to a maximum of 33 nauplii on the 15th day in larvae fed with second day nauplii (Fig. 1a, b). The consumption gradually decreased thereafter to 10 nauplii/day in the former group and 13.2 nauplii/day in the latter at the end of the experiment. The average consumption was higher in groups fed with second day *Artemia* nauplii (19.3 ± 1.16) than those fed with fresh nauplii (15.1 ± 0.94). The larvae fed with second day nauplii consumed a total of 656 nauplii to complete the fifth moult and those fed with freshly hatched nauplii consumed only 471 nauplii to complete the same number of moults. Though the consumption was higher, the phyllosoma required 34.0 days to complete the fifth moult when fed with second day nauplii, whereas, they required only 31.2 days to moult five times in the series fed with fresh nauplii (Table 1). Phyllosoma larvae fed with second day nauplii consumed 39% more food than those fed with fresh nauplii. In other words, the phyllosoma larvae increased its stomach capacity to 1.4 times and that the larvae fed to satisfy its energy demand rather than to fill its stomach to the maximum capacity (Rozin and Meyer, 1961). Vivekanandan *et al.* (1976) also found that the freshwater murrel *Ophiocephalus*

The size and activity of the prey also affected feeding in phyllosoma larvae. It is evident from the food consumption that the larvae preferred actively swimming large sized second day nauplii (0.85 mm) than slow moving freshly

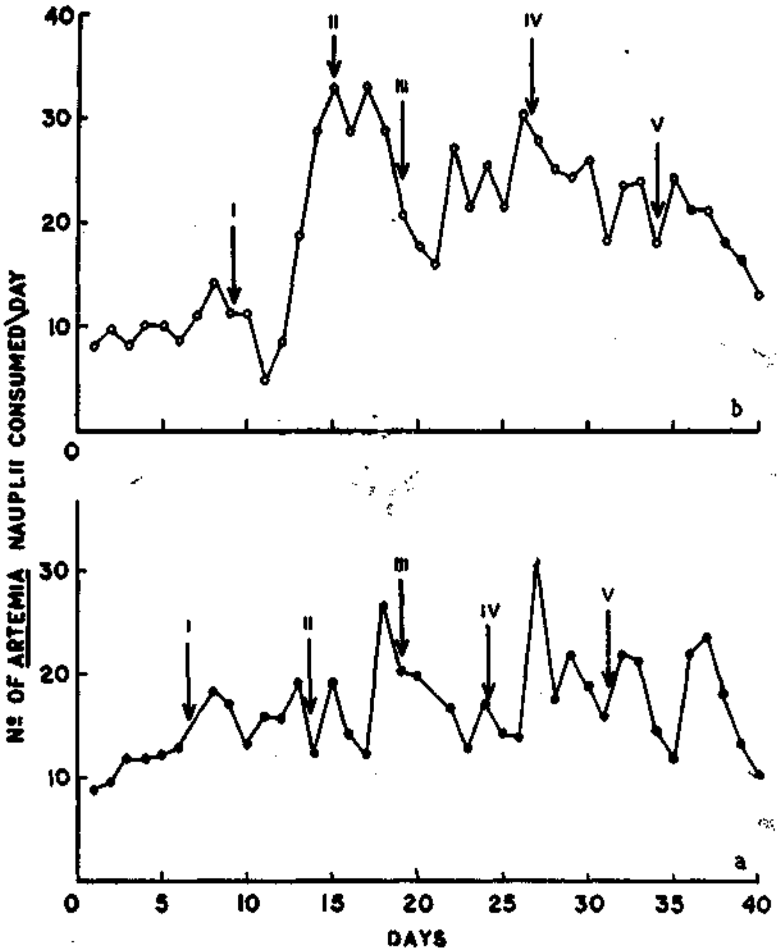

FIG. 1. Daily feeding pattern of phyllosoma larvae of *Panulirus homarus* in natural day-night periodicity: a. fed with freshly hatched *Artemia salina* nauplii and b. fed with second day *Artemia* nauplii. The arrows and numbers indicate the day of moulting and moult numbers of the larvae.

striatus consumed 33% more *Tilapia* muscle than goat liver to satisfy its energy demand as the goat liver contains 20% more energy than *Tilapia* muscle.

hatched nauplii (0.56 mm). Though the swimming activity of the phyllosoma larvae was not measured, visual observation showed that the second day nauplii swims faster than freshly hatched nauplii. The higher energy expenditure by the phyllosoma larvae to catch the actively swimming prey resulted in delayed moulting and growth.

The effect of 24 hr darkness and light on feeding and moulting are shown in Fig. 2a and b. The daily consumption of nauplii did not fluctuate much in both the series. However, the consumption gradually reduced at the end of the experiment. The observed reduction in consumption in later stages of reared larvae of *P. homarus* can probably be attributed at least in part to either a qualitative deficiency in the diet of *Artemia* nauplii or to the inability of the phyllosoma larvae to capture sufficient quantities, or both (Robertson, 1968; Vijayakumaran and Radhakrishnan, 1980). The food consumption was significantly low in both 24 hr D (11.1 ± 0.57 nauplii/day; students 't' = 6.45; p = <0.01 and 24 hr L (12.2 ± 0.45 nauplii/day; 't' = 4.9; p = < 0.01) when compared to natural day-night periodicity (15.1 ± 0.94 nauplii/day). Those exposed to 24 hr D consumed a total of 410 nauplii to complete the fifth moult in 37.0 days and those in 24 hr L fed 435 nauplii to complete the same number of moults in 35.5 days (Table 1). It may be recalled that the larvae reared under natural day-night conditions consumed 417 nauplii and moulted five times in 31.2 days. The "continuous light"

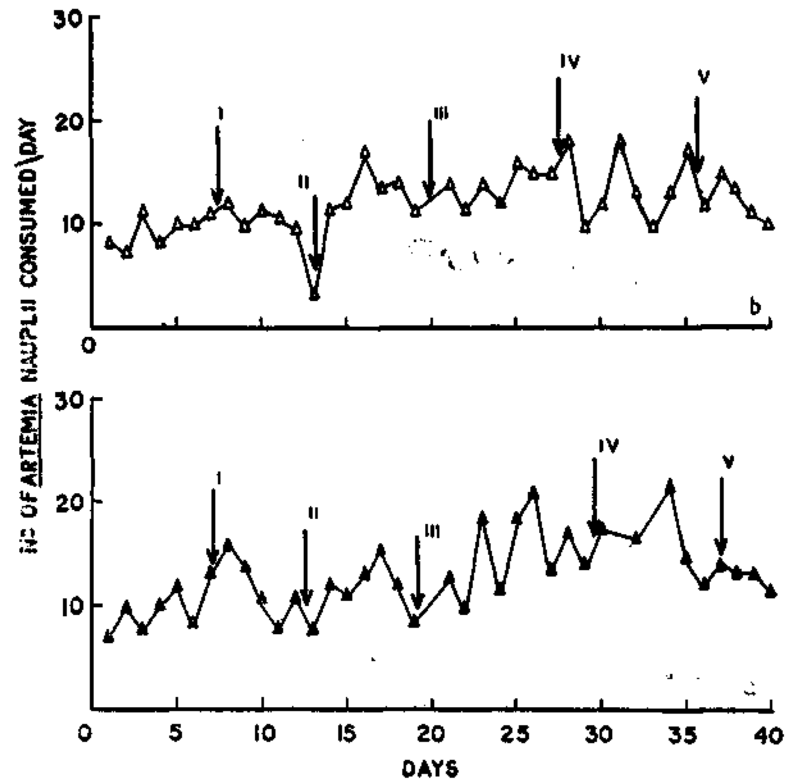

FIG. 2. Daily feeding pattern of phyllosoma larvae of *Panulirus homarus* fed with freshly hatched *Artemia salina* nauplii : a. in 24 hr. darkness and b. in 24 hr light. The arrows and numbers indicate the day of moulting and moult numbers of the larvae.

TABLE 1. *Effect of different photoperiods and size of prey on moulting frequency of phyllosoma larvae of* Panulirus homarus

	Natural Day-night Cycle I day nauplii*	Natural Day-night cycle II day nauplii*	24 hr darkness I day nauplii*	24 hr light I day nauplii*
Total days to moult 1	6.6±0.58 (6.0—7.0 days)	9.3±0.49 (9.5—10.0 days)	7.2±0.26 (7.0—7.5 days)	7.4±0.25 (7.0—7.5 days)
Total days to moult 2	13.6±1.2 (12.5—15.0 days)	15.0±0.65 (14.5—16.0 days)	12.5±0.25 (12.0—13.0 days)	13.3±0.64 (12.5—14.0 days)
Total days to moult 3	19.2±2.4 (17.5—22.0 days)	20.0±0.65 (19.5—21.0 days)	19.1±1.3 (17.5—21.0 days)	19.9±0.79 (19.9—20.5 days)
Total days to moult 4	25.1±4.2 (22.5—30.0 days)	26.7±1.2 (26.0—28.5 days)	29.4±1.8 (7.0—31.5 days)	27.6±0.63 (27.0—28.5 days)
Total days to moult 5	31.2±5.2 (27.0—37.0 days)	34.0±0.1. (33.0—35.0 days)	37.0±2.2 (34.0—39.5 days)	35.5±1.1 (34.0—36.5 days)

* Each average figure is based on about 15 individuals.

and "continuous darkness" would have affected the normal feeding activity of the phyllosoma larvae, resulting in slow growth. Chittlebourough (1975) reported depressed growth in juvenile *P. longipes cygnus* under conditions of continuous darkness. Aiken and Waddy (1976) also reported increased moulting frequency and moult increment in *Homarus americanus* larvae when exposed to long photoperiods. But Bliss and Boyer (1964) observed faster growth in the crab *Gecarcinus lateralis* reared in constant darkness. From the present

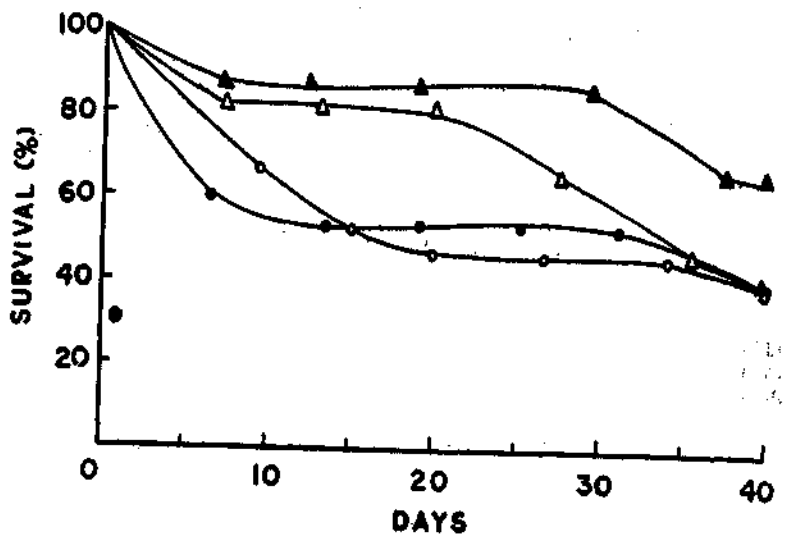

FIG. 3. Percentage survival of phyllosoma larvae of *Panulirus homarus* in natural day-night periodicity fed with freshly hatched nauplii (●), second day nauplii (O) and 24 hr darkness (▲) and 24 hr light (△) fed with freshly hatched nauplii.

study it appears that the tested photoperiods have altered the feeding rate first and in turn influenced the moulting frequency. It is clear from the observations that the moulting frequency was accelerated when the larvae consumed more nutritively rich food. Vivekanandan (1977) also concluded from his studies on *O. striatus* that environmental factors first altered feeding rate which in turn influenced metabolism and growth of fishes. The direct effect of darkness and light on growth through neuro-endocrine pathways is not known in phyllosoma larvae of *P. homarus*.

The percentage survival of phyllosoma larvae in the tested photoperiods during the experimental period is shown (Fig. 3). Though the growth rate was slow in 24 hr D, the maximum survival of the larvae (65%) was obtained in this photoperiod. The survival was low in all the other light regimes (40%). Templeman (1936) also reported higher survival rate of *H. americanus* larvae in complete darkness. At the end of the first moult of phyllosoma larvae, the lowest survival was in those reared in natural day-night periodicity fed with freshly hatched nauplii and the maximum in 24 hr D. In 24 hr L the highest mortality of larvae occurred during the fourth moult. The mortality of the larvae was caused by ciliate attack and change in feeding behaviour of the larvae. The late stage phyllosoma larvae seem to have difficulty in catching *Artemia* nauplii. A wide variety of protozoans attacked the phyllosoma larvae interfering in the swimming and feeding activity.

The positive phototactic behaviour of the phyllosoma larvae may be an advantage in feeding if an equally photopositive prey could be provided. Since long and short photoperiods does not have an accelerating effect on growth, alternating periods of light and dark and nutritionally rich food may be favourable for rearing phyllosoma larvae.

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OBSERVATIONS ON THE OLIVE RIDLEY TURTLE *LEPIDOCHELYS OLIVACEA* (ESCHSCHOLTZ) (FAMILY CHELONIIDAE) HATCHED AND REARED UNDER LABORATORY CONDITIONS

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ABSTRACT

One hundred and thirty four eggs of Olive Ridley turtle *Lepidochelys olivacea* (Eschscholtz) were incubated at an average temperature of 30.5°C under laboratory conditions. Thirty baby turtles emerged in three consecutive nights after 53 days of incubation. Of the remaining eggs, 69 did not hatch out and 35 failed to complete the development. Out of the 30 turtles that emerged, 28 died during the first 4 months, probably due to overcrowding and adverse conditions of the aquarium. The two turtles which survived, were reared in the aquarium for 1½ years, feeding with the meat of *Donax* sp., *Sepia* sp. and *Sardinella* sp. The morphological changes undergone and behaviour pattern of the turtles during the period of rearing were presented.

INTRODUCTION

LUTHER (1959) conducted an experiment at Mandapam Camp on incubation of eggs of Olive Ridley turtle and a few hatchlings emerged, had died. Mawson (1921) incubated eggs of Green Turtle *Chelonia mydas*; the incubation was a success, but she had not stated anything about the fate of the hatchlings. Bustard and Greenham (1968) and Bustard *et al.* (1969) had made reports on successful incubation of Green turtle and Loggerhead (*Caretta caretta*) turtles; but they had not made any report on rearing. Hornell's (1927) rearing of babies of Hawksbill (*Eretmochelys imbricata*) and Green turtles was not successful. Moorhouse (1933) reported 10-24% success in incubation of Green turtle eggs removed from oviducts and 41-86% success in twelve natural nests. Hendrickson (1958) had given an account on incubation of Green turtle eggs in hatchery and some accounts on growth. Jones (1959) made an attempt to incubate Leatherback turtle *Dermochelys coriacea* eggs, but did not hatch out. Hirth (1971) had given a brief account on culture of turtle and Milne (1972) had given a short note on turtle culture in British West Indies and Australia. Boonlert Phasuk and Sayan Rongmuangsart (1973) had given an account on the Ridley turtle *Lepidochelys olivacea olivacea* Eschscholtz in captivity and the effect of food preference.

The author is greatly indebted to Dr. C. S. Gopinadha Pillai, CMFRI for helpful suggestions for improvement of the manuscript.

MATERIAL AND METHODS

One hundred and thirty four eggs laid at 0030 hrs, on 31st January, 1973 on the coast of Mulli Island in the Gulf of Mannar, about six metres above spring high tide level were collected at 0600 hrs. and placed softly one by one in an empty biscuit tin above a layer of coral sand of 4 cm height. The lateral space 3 cm left in the tin was filled with the same type of sand. The eggs in the tin stood for a height of 13 cm and the sand was placed over the eggs for a height of 4 cm. The tin had a height of 35.4 cm and sides 24 cm (square). This semi-natural nest was brought to the laboratory by a canoe and placed on a wooden table in the laboratory.

A thermometer was placed vertically on the sand at the centre of the nest. The temperature was recorded daily at four consecutive periods : 0600, 1230, 1800 and 2400 hrs.

Once in four days 300 ml distilled water was sprinkled over the sand to keep the nest moist.

The hatchlings were measured, tagged and kept in a glass tank (121.5 × 60.5 × 33.0 cm) with sea water open circulation in the Aquarium. They were initially fed with the meat of *Donax* sp. for a week and thereafter with the meat of *Sepia* sp., *Sardinella* sp., *Pseudosciaena* sp., *Pellona* sp., *Cynoglossus* sp., *Hemirhamphus* sp., *Selaroides leptolepis*, *Dussumieria* sp., *Thrissocles* sp., *Anchoviella* sp., *Upeneus* sp., *Sillago sihama* and *Penaeus* sp. at 1030 hrs. and the unconsumed meat was removed at 1600 hrs. every day.

The nest was opened on the 8th day after the first emergence of the hatchlings to see the fate of the remaining eggs.

While cleaning the tank in the morning and evening the baby turtles were allowed to bask. The two babies survived were put together in one tank till the sixth month and put thereafter in separate tanks.

Water depth was lowered when the babies found difficult to swim and raised when they were active.

The per cent conversion efficiency was determined by the equation (Robert, 1971). :

$$\frac{\text{Grain}}{\text{Total food consumed}} \times 100$$

RESULTS

On the 54th day (25 March, 1973) of incubation at the average temperature of 30.5°C seventeen baby turtles (56.7%) emerged between 2015 hrs. and 2400 hrs. Six babies (20%) emerged between 0000 hr. and 0100 hr. on the 55th day (26 March, 1973). Five babies (16.7%) emerged between 2300 hrs. and 2350 hrs. on the same day and two babies (6.6%) emerged at 1200 hrs. on the 56th day (27 March, 1973). Thus in total thirty hatchlings (22.39%) emerged. Thirty five hatchlings (26.12%) failed to emerge. Sixty nine eggs (51.5%) failed to hatch out. Two babies (6.7%) survived and the other 28 babies died within four months.

The two survived babies No. 5451 and 5452 thrived well on carnivorous diet. The baby turtle No. 5451 weighed 16 gm and measured 41 mm carapace length at emergence ; at the end of one year it weighed 3016.9 gm and had a carapace length of 267 mm; at the end of 1½ years it weighed 5600 gm and its carapace measured 345 mm. The baby turtle No. 5452 weighed 17 gm and measured 40 mm carapace length at the time of emergence ; at the end of one year it weighed 2012.6 gm and had a carapace length of 237 mm at the end of 1½ years it weighed 4087 gm and the carapace measured 307 mm. The average monthly weight and length increments are given in Table 2.

OBSERVATIONS

Eleven different characters observed are recorded here.

Positive heliotropism

The newly hatched baby turtles were placed in a white plastic tray and photographed at about 1000 hrs. on a verandah. When they were in the tray they were very active and the direction of their movement was towards the position of the sunlight.

TABLE 1. *Details of food consumed by the baby Olive Ridley turtle* Lepidochelys olivacea *(Eschscholtz) No. 5451 and 5452*

Months	Baby turtle No. 5451		Baby turtle No. 5452	
	Food consumed per month (gm)	% of food consumed per body weight per day	Food consumed per month (gm)	% of food consumed per body weight per day
October 1973	1808	5.74	829	4.25
November	1954	4.61	1001	4.39
December	2093	3.71	1315	4.04
January 1974	2196	3.29	1215	2.89
February	2922	1.29	1473	3.10
March	3265	3.95	1917	3.42
April	4110	4.24	1391	2.33
May	3789	3.53	1731	2.84
June	5271	4.54	2673	3.97
July	3676	2.97	2581	3.32
August	4352	2.83	3423	3.50
September	4238	2.65	4033	3.53
Total	37674		23582	

Vigour by basking

Whenever the baby turtles in the rearing tanks were found too weak to swim and appeared to be drowned they were at once taken out, washed in fresh sea water and placed on dry floor for basking. After half-an-hour the babies were replaced in the water. The babies began to swim with vigour and to breathe; they had lost their weakness by means of basking.

Duration of submergence in water

The baby turtles were able to remain under the water motionless from three to five minutes from the third month to one year old and from five minutes to half-an-hour from one year to $1\frac{1}{2}$ year old.

Anxiety for food at the feeding time

When the feeding time approached and the feeding actually delayed the babies used to raise their heads very often towards the direction from where the food was supplied.

Fear for seaweed

The seaweeds *Gracilaria edulis* and *Sargassum* sp. were supplied on different occasions to the baby turtles; they became terrified at the very sight of the seaweeds and did not eat even a bit from those; perhaps it might be due to that they were habituated to feed on carnivorous diet. Boonlert Phasuk and Sayan Rongmuangsart (1973) had fed the hatchlings with the Green alga *Enteromorpha intestinalis*, the shore plant *Ipomoea pes-caprae* and the turtle grass *Thalassia testudinum* and the hatchlings showed the best preference for the turtle grass.

Movements in the water

The movements of the baby turtles during the first two months after the emergence were mainly on the surface of the water in the rearing tank. For feeding only they would dive to the bottom. The two survived babies exhibited anticlockwise movement along the sides of the tank from the third month to one year old.

After one year they showed clockwise movements. The reason for the initial surface movements, second anticlockwise and the third clockwise movements is not known.

Mutual behaviour

The two survived baby turtles were put in separate tanks to study the per cent conversion efficiency. Whenever they were put together unexpectedly they showed immense restlessness by flapping their flippers and swimming hither and thither vigorously in terror as if a stranger had intruded to disturb. After about half-an-hour of restlessness they used to become calm. When they were together in the restful stage in the rearing tank, the No. 5452 baby would first become active and bite the flipper of the baby No. 5451 which to its best would not allow itself to be bitten by maintaining certain calm and subtle movements; if by chance its flipper was bitten, it, all of a sudden, lost its restfulness and swam from the surface to bottom, from bottom to surface, slantingly and sometimes perpendicularly. They had no contention for the food supplied.

Reaction to noise

When there would be perfect silence in the rearing room and some sudden noise was made unexpectedly or with intention either by bolting or putting some material the baby turtles struck with fear made loud noise by flapping their flippers, swimming violently and spraying the water throughout the rearing room.

Taming

The baby turtles were tamable. They became tame to the author as they were acquainted by feeding, washing, basking and taking measurements. When any stranger tried to touch them they used to dive to the bottom of the tank and disappear from their vicinity.

Moulting

The moulting was not uniform for all the laminae; it was just casting off bits of laminae from carapace, plastron and head. The frequency of moulting was more till one year old and some bits of laminae could be seen on the bottom of the tank on almost all mornings. When the babies were removed from water and kept in a bucket for basking moulting took place rapidly; on getting dry the surface portions of laminae would rise up and fell down on wiping. The moulting locations in the body in the order of predominance were laterals, centrals, plastron laminae and head laminae.

Body colour change during growth

The babies newly emerged from the nest had a sooty black colour and a thin white margin around the carapace and posterior edge of each flipper. The gapes were grey, throat dark and the base of the neck lighter. There were three white spots on the femoral laminae, one in the middle and the other two at the upper part of the laminae, one on each of the pair. The middle white spot is the point of attachment of the yolk with the developing embryo for supply of nutrients (Pl. I B, C).

By the time of growth the intensity of the body colour was diminishing; the carapace margin became light yellow.

Six months old baby turtles

Dorsal view: In turtle No. 5451 the grey margin in the fore flippers were dominant and seams became grey. In turtle No. 5452 the intensity of the sooty black colour slightly disappeared and margins appeared slightly grey.

Ventral view: In turtle No. 5451 the margin of the proximal part of fore flippers and neck became grey. The black patches on the plastron were not so intense. In turtle No. 5452 the margin of the proximal part of fore flippers

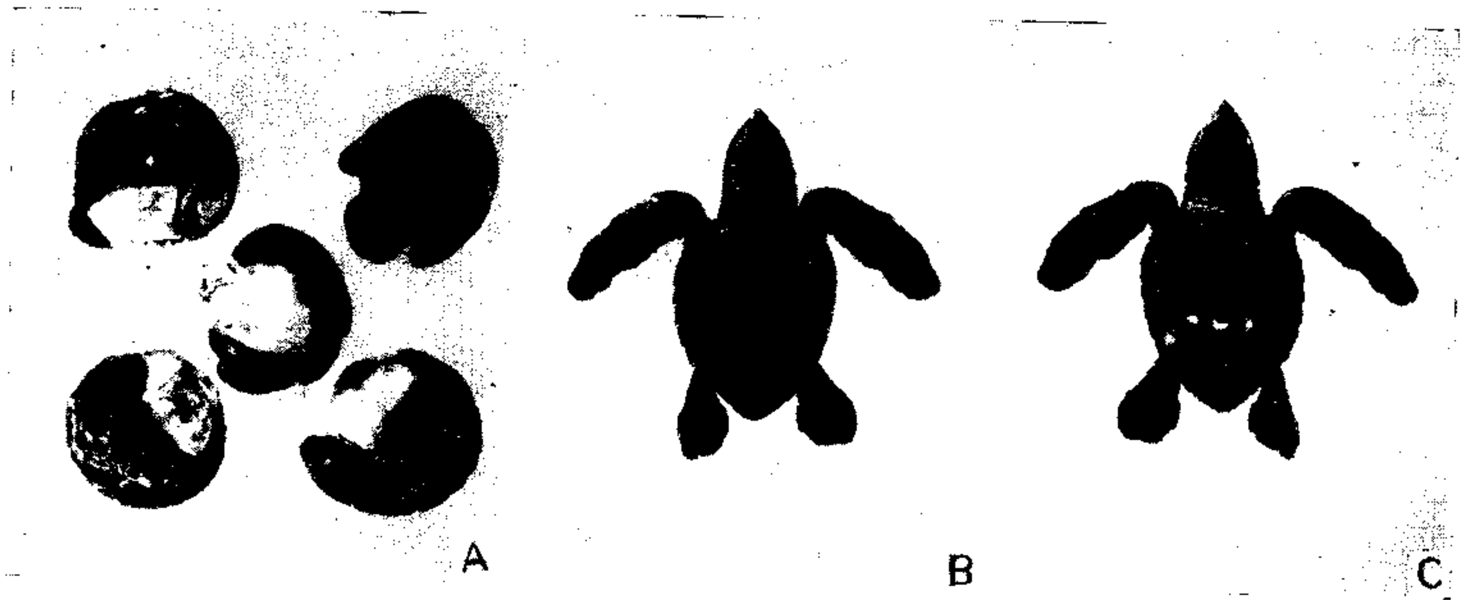

PLATE I. Emerged and nonemerged baby Ridley turtles *Lepidochelys olivacea* (Eschscholtz) by incubation of eggs in the laboratory: A. A few of the under-developed babies nonemerged; B. One of the newly hatched babies—dorsal view and C. The same hatched baby—ventral view.

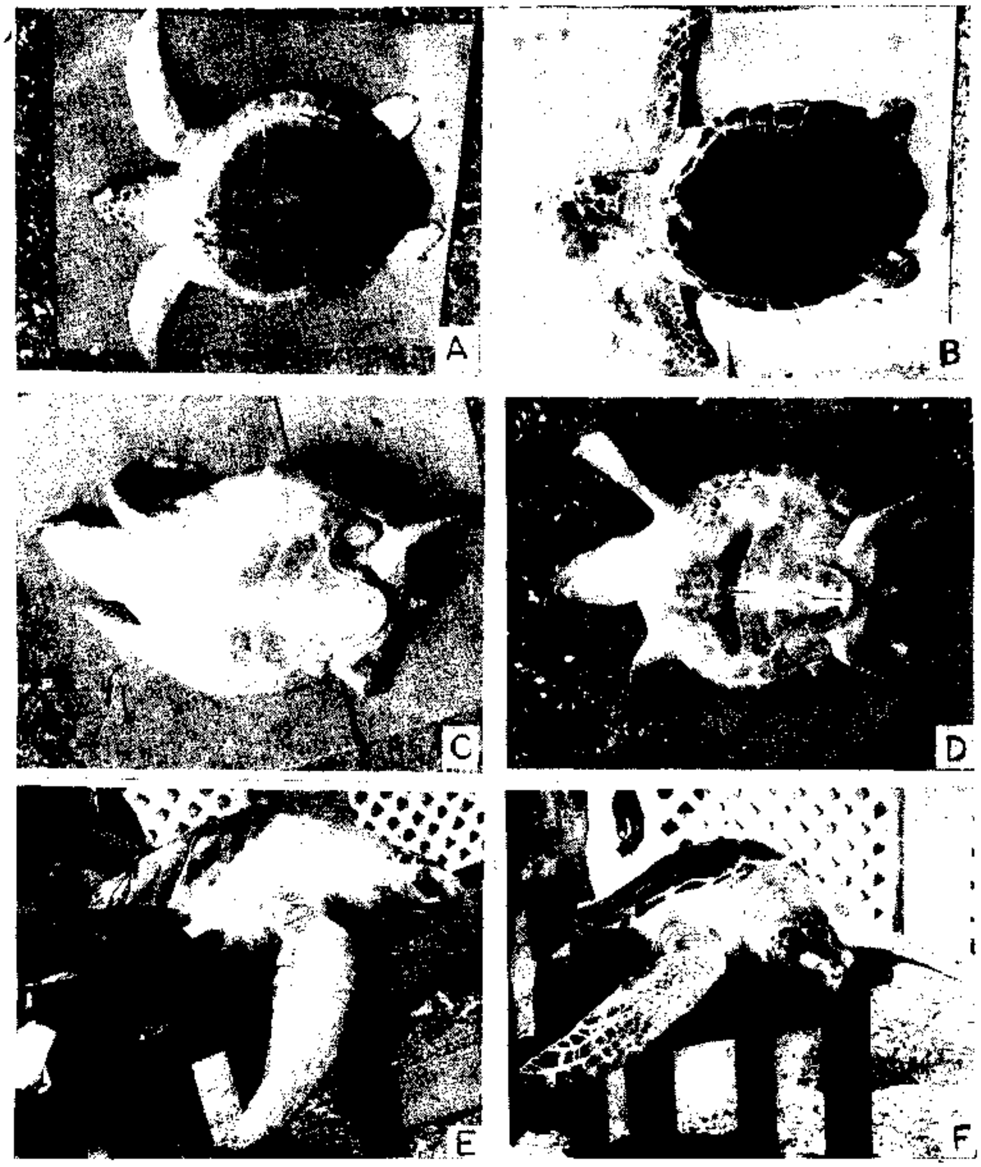

PLATE II. One and-a-half year old baby Ridley turtles *Lepidochelys olivacea* (Eschscholtz) No. 5451 and 5452 ; A. Dorsal view of baby No. 5451 ; B. Dorsal view of baby No. 5452 ; C. Ventral view of baby No. 5451 ; D. Ventral view of baby No. 5452; E. Frontolateral view of baby No. 5451 and F. Frontolateral view of baby No. 5452.

and the neck contained black colour. The black patches on the plastron were intense.

Lateral view : In turtle No. 5451 the dorsal ridges were visible. The rostral and the lateral margins of fore flippers became grey and there were grey patches in front of each eye. In turtle No. 5452 the dorsal ridges were visible. The rostral was grey. The lateral margins of the fore flippers were not so grey as in the other baby. The grey patch in front of each eye was as that in the other baby.

Front view : In turtle No. 5451 the grey colour along the front margin of fore flippers appeared dominantly. The central ridge was clearly visible. The grey colour in front of the eyes, on the rostral and surrounding the nasals were very clear. In turtle No. 5452 the grey colour along the front margin of the fore flippers was not dominant. The central ridge was clearly visible. The grey colour in front of the eyes, on the rostral and surrounding the nasal was clearly visible.

One year old baby turtles

Dorsal View : In turtle No. 5451 the grey colour was dominant on fore flippers, head seams, laterals, marginals and hind flippers. The anterior half of the carapace was showing shades of grey colour. In turtle No. 5452 the grey colour was not so dominant on fore flippers, head seams, laterals, marginals and on hind flippers.

Ventral view : In turtle No. 5451 the black colour almost vanished in flippers and the proximal parts of the flippers had changed into grey. The plastron was yellowish grey. In turtle No. 5452 the flippers retained black colour in more areas than in the other baby. The proximal parts of the flippers were grey. The plastron was light yellow grey.

Lateral view : In turtle No. 5451 the fore flippers had become almost grey. In turtle No. 5452 the grey colour was only in seams.

Front view : In turtle No. 5451 the front margins of fore flippers were grey. The head and neck had become much more grey. In turtle No. 5452 the front margins of fore flippers were slightly grey. The head and neck retained more black colour.

One-and-a-half year old baby turtles

Dorsal view : In turtle No. 5451 almost all parts except some laminae on head and hind parts of carapace had become grey. The precentral and the succeeding three centrals had become almost grey. The four pairs of anterior laterals had almost become grey. The marginals except the hind three had become grey. In turtle No. 5452 the carapace retained black colour. The fore flippers retained the black colour in the laminae of the middle and hind portions. The head was almost black. The hind flippers retained black laminae but grey colour had occupied more parts (Pl. IIA, B).

Ventral view : In turtle No. 5451 the plastron was yellowish grey. The flippers had become grey. In turtle No. 5452 the plastron was yellowish grey. The flippers retained uniform very light shades of black colour (Pl. II C, D).

Fronto-lateral view : In turtle No. 5451 it had become almost grey except slight black patches on laminae of head and carapace. The hind part of the plastron remained slightly black. In turtle No. 5452 almost half of the area on head, neck and flippers had become grey, but many laminae partially retained black colour. The carapace remained black except anterior seams (Pl. II E, F).

The No. 5451 turtle underwent prominent colour change from 11½ month onwards. The middle portion of the second, third and fourth centrals (ridges) and the lateral periphery of the three anterior pairs of laterals exhibited dark grey radiating streaks; gradually the change of colour spread to the surrounding areas. After 14th month the remaining centrals began to appear grey. The central portion of laterals remained black. From 16th month onwards the central portions of the anterior three centrals also began to appear grey. When it attained the age of 1½ years the original black colour remained in light shades in the central portion of laterals and nearly one half of the carapace at the hind end retained the black. The No. 5452 turtle remained without any considerable colour change except that the intensity of the black colour slightly diminished and underwent some minor changes as explained before.

Discussion

The egg laying season of the Olive Ridley turtles *Lepidochelys olivacea* (Eschscholtz) is from September to January. Hare Island, Valai Island, Mulli Island and Dhanushkodi Coast are the main nesting sites in the Gulf of Mannar. Carr (1952) had reported that the egg laying season of Ridley turtles on Indian Coast is from September to December. Luther (1959) had reported an incident of egg laying of a Ridley turtle in October. The author had observed egg laying in December and January.

The range of eggs per clutch is 50-138 from the observation of the author. Deraniyagala (1939) had reported the range as 90-135 eggs.

The eggs hatched out after 53 days of incubation in the laboratory conditions ; the incubation period was counted from the time of egg laying in the natural nest. Deraniyagala (1939) in Sri Lanka recorded the incubation period as 50 to 60 days.

The author moistened the nest with distilled water as mentioned under Material and Methods by Bustard and Greenham (1968). The mean temperature during the 53 days of the incubation period at 0600 hr was 29.3°C, at 1230 hr 30.5°C, at 1800 hr 31.8°C and at 2400 hr 30.5°C. The average of these four is 30.5°C.

All the thirty baby turtles emerged in three nights. In natural nests also the babies emerge in nights (Handrickson, 1958) ; that instinctive character is a natural protective device to safeguard themselves from lethal temperatures of the strongly irradiated beaches and from predators like dogs, foxes, pigs, crows, etc. (Hirth, 1971).

The hatchlings exhibited variation in central and lateral counts. The central laminae varied from 7 to 9 ; five babies had 7 centrals, twelve babies had 8 centrals and thirteen babies had 9 centrals. The laterals varied from 4 to 9 ; one baby had 9 left laterals, two babies had 5 left laterals, ten babies had 7 left laterals and seventeen babies had 6 left laterals ; as regards right laterals, one baby had 4, two babies had 8, four babies had 7, five babies had 5 and eighteen babies had 6. Coming to marginals one baby had 14 on the left and 12 on the right, another had 12 on the left and 11 on the right, another had 13 on the left and 12 on the right, four babies had 13 on the left and 13 on the right and 23 babies had 12 on the left and 12 on the right. From this data when the majority counts are considered normal, a baby having 8 centrals, 6 pairs of laterals and 12 pairs of marginals is normal. Deraniyagala (1939) had recorded 5 to 8 laterals (coatals) on each side as range ; but from the author's observations of the thirty babies the range may be modified as 4 to 9.

Boonlert Phasuk and Sayan Rongmuangsart (1973) found that the hatchlings preferred oyster meat to all other types of meat diet. *Sardinella* sp. meat was also supplied.

The average daily food consumption per body weight was 3.61% (range : 1.29%-5.7%) and 3.47% (range : 2.33%-4.39%) for the No. 5451 and 5452 baby turtles respectively (Table 1). The per cent conversion efficiency

TABLE 2. *Length and weight increments of the baby Olive Ridley turtles* Lepidochelys olivacea (*Eschscholtz*) *No.* 5451 *and* 5452

Period of age	Weight increment (gm)		Average monthly weight increment (gm)		Length increment (mm)		Average monthly length increment (mm)	
	Turtle No. 5451	Turtle No. 5452	Turtle No. 5451	Turtle No. 5452	Turtle No. 5451	Turtle No. 5452	Turtle No. 5451	Turtle No. 5452
First 6 months (March 1973 to Sept. 1973)	868.0	477.0	144.67	79.5	135.0	101.0	22.50	16.83
Second 6 months (Sept. 1973 to March 1974)	2132.9	1518.6	355.48	253.1	91.0	96.0	15.17	16.00
Third 6 months (March 1974 to Sept. 1974)	2583.1	2074.4	430.52	345.7	78.0	70.0	13.00	11.67
First one year (March 1973 to March 1974)	3000.9	1995.6	250.08	166.3	226.0	197.0	18.83	16.42
1½ Years March 1973 to September 1974)	5584.0	4070.0	310.22	226.1	304.0	267.0	16.89	14.83

in the two babies was not uniform ; it was high during September to January, slightly came down in February and March, further declined in April, May and June and inclined in July, August and September. The great reduction in per cent conversion efficiency in April, May and June might be due to the rise in temperature. The average monthly per cent conversion efficiency was 14.37 (range : 6.01-26.60) and 15.76 (range : 3.02-24.64) for the No. 5451 and 5452 turtles respectively.

The mortality during the first month was 33.3%, during the second month 53.3%, no mortality in the third month and 6.7% during the fourth month. Boonlert Phasuk and Sayan Rongmuangsart (1973) reported that the mortality was 33% during the first six months and according to them the aquarium conditions also seemed to influence the mortality rate of baby turtles. The overcrowding of the turtles in the rearing tank may also be a reason for the mortality.

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PRODUCTION OF COPEPODS IN AN OUTDOOR CULTURE TANK

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ABSTRACT

Production of copepods in a 3000 litre capacity outdoor mass culture tank has been studied by periodical sampling. The culture was maintained by fertilizing the filtered sea water using cowdung, groundnut oil cake, Super Phosphate and Urea in the ratio 80 : 10 : 1 : 1 to enhance the phytoplankton production and thereby that of the grazers. The change in the hydrological parameters due to evaporation, or dilution due to rain has been correlated to the trend in the production of the species belonging to the genera *Cyclops*, *Oithona* and *Pseudodiaptomus*.

The species *Pseudodiaptomus annandalei* Sewell, dominated in the culture system and reached its maximum density of 22,000 per litre at 28‰ salinity. The utilization of copepods, copepodites and nauplii in rearing crustacean and fish larvae has been discussed.

INTRODUCTION

COPEPODS serves as an important link in the marine food chain. The mass culture of these organisms assumes an added importance in intensive aquaculture practices involving rearing of larval stages of fishes and crustaceans. Much attention has been focused in recent years on culturing copepods under controlled conditions since they form an inevitable live feed for fish and crustacean larvae.

Various workers have attempted to mass culture different species of copepods. However, the technology for the mass culture and production of copepoda for aquaculture has not yet been established on a global basis. Most of the available work are limited to the studies on the life history and biology of copepoda. Jacobs (1961), Mullin and Brooks (1967) and Kahan (1979) report small scale experimental culture of copepods. Zillioux (1969) is the first to describe a continuous culture system for planktonic copepods using synthetic sea water in 100 l capacity tanks. While discussing the problems associated with the culture of marine copepods Gonzalez *et al.* (1972) opined that one of the major problems encountered in obtaining dependable cultures of copepods for laboratory studies appears to be that of finding a suitable medium. Using artificial sea water, the culture rarely exceeded 100 l capacity. Kitajima (1973) based on his experiments opined that the harpacticoid copepod *Tigriopus japanicus* is the most promising copepod for mass culture. The potentiality of the copepod *Nitocra spinipus* was pointed out by Abraham and Gopalan (1975) and Gopalan (1977). Goswami (1977) suggested that *Laophante setosa* can be easily reared and maintained since the adult can tolerate wide fluctuations in temperature and salinity. Ikeda (1973) indicated that small sized neritic or brackishwater copepods are easy to rear artificially as compared with those of large sized species in the open seas. Hirata *et al.* (1979) polycultured the rotifer *Brachionus plicatilis* and the harpacticoid copepod *Tigriopus japonicus* in 500 l capacity tanks using a feed back system.

Heinle (1970) was the first to study the population dynamics of exploited cultures of calanoid

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copepods. Based on the culture experiments on *Oithona* spp. Thompson and Easterson (1977) estimated the production of Oithonids in the estuarine wateıs of Cochin for a period of one year. During the present investigation, the population characteristics of three species of copepods *viz. Pseudodiaptomus annandalei* Sewell *Oithona hebes* Giesbrecht and *Cyclops* sp. reared in 3000 litre capacity outdoor culture tank has been studied in relation to hydrological conditions. The production rate has been estimated for *P. annandalei.*

The authors are grateful to Dr. E. G. Silas, Director, Central Marine Fisheries Research Institute, Cochin for his keen interest in this work and for constant encouragement.

Material and Methods

The culture was maintained in 3000 l capacity out-door culture tank. The water was fertilized using cowdung, groundnut oil cake, Super Phosphate and urea in the ratio 30 : 10 : 1 : 1 to enhance the phytoplankton production and thereby the copepods. The water was continuously aerated. Weekly collections were obtained by stirring the water and an alliquot of 1 litre sample was collected during the months of May to August in the year 1979. The collections were preserved in 5% formaldehyde. The counts were made for the adults, copepodites and nauplii separately for the three species. Along with each sampling, measurements of salinity temperature and oxygen were also made.

The duration of development of *P. annandalei* was determined by maintaining a culture of gravid females under laboratory conditions. During this period they were fed with a mixed culture of phytoplankton. The time taken from hatching of the egg to the development of Copepodite-1 was taken as the duration for naupliar development and the duration from Copepodite-1 to the development of Copepodite VI (*i.e.* adult) was taken as the life span of copepodite stage.

Hydrological Features

The hydrological conditions in the culture tank were greatly influenced by evaporation in the sun or dilution due to rain (Fig. 1).

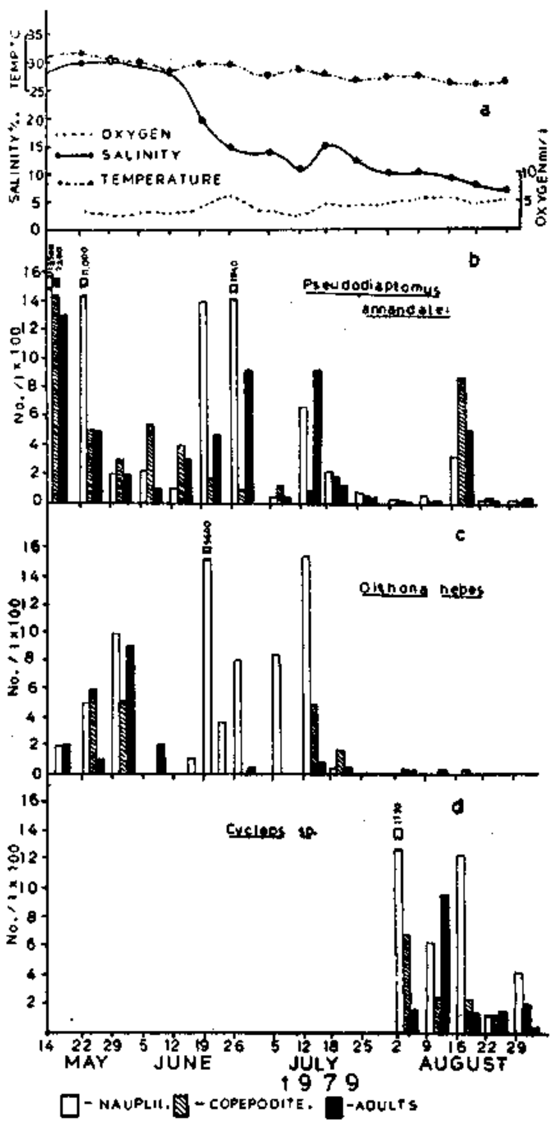

FIG. 1 a. Salinity (‰), Oxygen (ml/l) and Temperature (°C) in the mass culture tank ; b. Population density (No/l) of *Pseudodiaptomus annandelei* ; c. Population density (No/l) of *Oithona hebes* and d. Population density (No/l) of *Cyclops* sp.

The temperature of water varied from 26.1 to 31.0°C. A gradual decrease in temperature during the period of observation was mainly due to the onset of southwest monsoon. The salinity varied between 6.75 to 30.0/‰. The decrease of salinity was due to dilution by rain during the observation period. However, the salinity fluctuated and showed an upward trend due to evaporation during the middle of July. The dissolved oxygen varied between 2.6 to 5.7 ml/l. Though the increase in dissolved oxygen was mainly due to the bloom of phytoplankters, there was not much fluctuation since the culture was constantly aerated.

where B=number moulted per day; E= number of developing individuals of a particular stage per litre; and D=mean duration of development.

The instantaneous birth rate (b) was calculated using the formula:

$$b = ln\ (l + B) \tag{2}$$

The instantaneous population growth rate (r) was calculated using the expression:

$$r = \frac{ln\ N_t - ln\ N_o}{T} \tag{3}$$

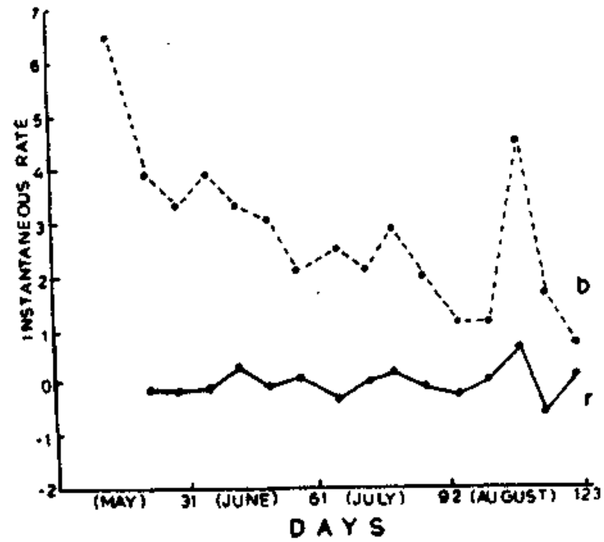

FIG. 2. Instantaneous birth rate (b) and population growth curve (r).

RESULTS AND DISCUSSION

Production of P. annandalei

To estimate the production of *P. annandalei*, the model proposed by Edmondson (1960, 1971) and applied by Thompson and Easterson (1977) has been followed in principle. The natality of the copepods was calculated by using the formula:

$$B = \frac{E}{C} \tag{1}$$

where N_o = initial population size; N_t = the size of the population in the following sample; and T = the time interval in between the sampling.

The instantaneous mortality rate (d) was calculated by the expression:

$$d = b - r \tag{4}$$

The production of copepods (P) was calculated from the natality rate for the said period

TABLE 1. *Calculated production of* Pseudodiaptomus annandalei *during the months of May-August in* 1979

Date	Nauplii (No./l)	Days*	Natality of Copepodites (No./l/day)	Copepodites (No./l) E	Days* D	Copepods (No./l) N	Natality of Copepods (No./l/day) B	Instantaneous birth rate b	Population growth r	Mortality d	Production (No./l) Pno	Pno/l/day
14-5-1979	13,500	7	1,929	7,200	11	1,300	655	6.49	—	—	—	—
22-5-1979	11,000	7	1,571	500	11	500	46	3.85	—0.12	—3.97	5,48,100	68,513
29-5-1979	200	7	29	300	11	200	27	3.33	—0.13	—3.46	6,650	950
5-6-1979	220	7	31	550	11	100	50	3.93	—0.10	—4.03	3,450	493
12-6-1979	100	7	14	400	11	300	36	3.31	+0.30	+3.01	2,800	400
19-6-1979	1,400	7	200	160	11	480	15	2.77	—0.08	—2.85	8,190	1,170
26-6-1979	1,840	7	263	80	11	920	7	2.08	+0.09	+1.99	5,600	800
5-7-1979	40	7	6	120	11	40	11	2.48	—0.35	—3.83	1,920	213
12-7-1979	760	7	109	80	11	44	7	2.08	+0.01	+2.07	168	24
18-7-1979	320	7	46	180	11	120	16	2.83	+0.17	+2.66	738	123
25-7-1979	80	7	11	60	11	40	6	1.95	—0.16	—2.11	800	114
2-8-1979	30	7	4	18	11	6	2	1.09	—0.24	—1.33	92	12
9-8-1979	58	7	8	17	11	6	2	1.09	0.00	+1.09	12	2
16-8-1979	315	7	45	870	11	501	79	4.38	+0.63	+3.75	19,520	2,789
22-8-1979	20	7	3	40	11	12	4	1.61	—0.62	—2.23	19,238	3,206
29-8-1979	20	7	3	10	11	26	1	0.69	+0.11	+0.58	114	16

* Duration of development.

(t) using the equation proposed by Galkovskaya (1971):

$$P = B_t \tfrac{1}{2}(N_o + N_t) \qquad (5)$$

The calculated daily production of *P. annandalei* has been given in Table 1.

The instantaneous birth rate curve (b) shows wide fluctuations and is always positive (Fig. 2). However, there is a gradual decrease from 6.49 to 0.69 during the period of observation. The population growth curve (r) is more negative and is almost parallel with the

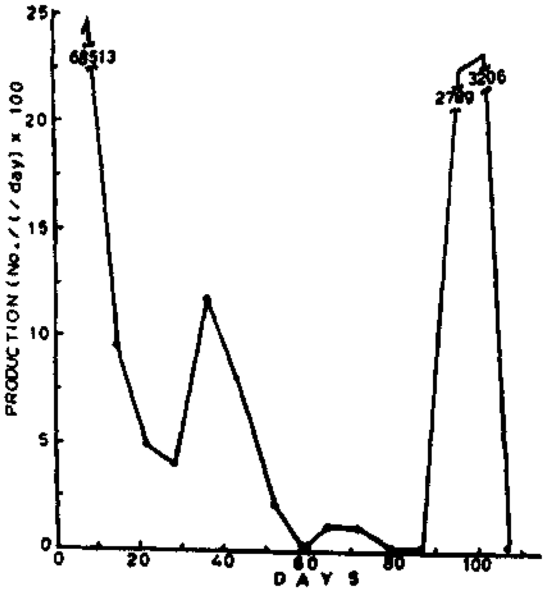

FIG. 3. Production of *P. annandalei* (No/l/day).

instantaneous birth rate from June onwards. This evidences constant mortality operating in the culture system. This may also be related to the hydrological condition of the culture system wherein the salinity decreased with the onset of southwest monsoon. The population growth curve without violent fluctuations shows high order of stability during the period of observation.

The mean daily production for *P. annandalei* varied between 68,513 to 2/litre (Fig. 3). The production decreased with the decrease in salinity. The fluctuations in *P. annandalei* population is not due to lack of food. As it was a closed culture system the water was regularly fertilized for stimulating phytoplankton bloom. There was not much change in the temperature, though there was a decrease with the onset of southwest monsoon. The *P. annandalei* population peak coincided with the period of dilution and recovery of the culture medium and as such salinity acted as the controlling factor.

With the decrease in salinity from 15‰ onwards the *Oithona hebes* population also decreased and the disappearance of this species in the culture tank was noted when the salinity decreased below 9.93‰. The appearance of the copepod *Cyclops sp.* coincide with the decrease of salinity in the culture medium and reached its maximum abundance at 9.93‰. The population succession in the culture tank was mainly due to the change in the salinity.

Lebour (1919 a, b) reported copepods as the most common food of nearly all very young fishes and Blaxter (1965) concurred. Larvae of Atlantic herring *Clupea harengus* reared in the laboratory, selected copepod nauplii and copepodites as food (Rosenthal, 1969). Blaxter (1969) implied that copepod nauplii were the food of laboratory reared pilchard, *Sardina pilchardus* larvae, based upon an examination of the composition of wild plankton offered as food and from the analyses of stomach contents of larvae collected at sea. Detwyler and Houde (1970) also found that copepod nauplii and copepodites were suitable as food for larval and adult fishes. Hirata (1977) cultivated zooplankton for fundamental research as well as for prawn seed production. Yamasaki (1977) personal communication opined that Harpacticoid copepod *Tisbe sp.*, showed potential as a substitute to *Artemia* or *Brachionus* which is used as food for fin fish and crustaceans secondary to *Artemia*.

Because copepods are universally accepted as food by fin fishes and crustaceans, development technique for mass culture of these organisms would greatly benefit rearing of larval fish.

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Proc. Symp. Coastal Aquaculture, 1986, **4** : 1281-1285

EFFECTS OF FOOD DENSITY ON FEEDING AND MOULTING OF PHYLLOSOMA LARVAE OF THE SPINY LOBSTER *PANULIRUS HOMARUS* (LINNAEUS)

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ABSTRACT

Feeding response of the laboratory reared second stage phyllosoma larvae of the spiny lobster *Panulirus homarus* was studied individually on a diet of newly hatched *Artemia salina* nauplii. The density of food affected feeding and moulting under experimental conditions. With increase in density of *Artemia* nauplii from 1 to 100/60 ml, consumption also increased from an average of 0.5 to 27.8 nauplii/day. Percentage consumption increased from 50 when offered 1 nauplius/ 60 ml to 80 at a ration of 5 nauplii and thereafter decreased gradually to 27.8 at a density of 100 nauplii/60 ml.

Density showed positive correlation (p 0.05) with the number of nauplii consumed. The second stage phyllosoma required 30 days to complete third moult at a food density of 5 nauplii/60 ml and only 17 days at a density of 60 to 100/60 ml. Since there was no appreciable difference in moulting frequency of individuals offered more than 60 nauplii, maximum growth of phyllosoma may be obtained at a food density of 60 nauplii/60 ml.

INTRODUCTION

ESTIMATION of optimum feeding level is an important factor in controlled culture of larval stages of many fish and shellfish. Optimum rations help to prevent cannibalism by underfeeding, fouling of water by overfeeding and to avoid wastage of larval foods which are generally expensive. Studies on optimum food requirement of phyllosoma larvae of palinurid lobsters are limited (Inoe, 1965; Saisho, 1966) and no such study is reported for Indian lobsters.

All attempts to rear the larvae of palinurids in the laboratory from hatching to puerulus have been unsuccessful due to lack of suitable feeds to meet the changing nutritional requirements. However early larval stages are successfully fed on *Artemia* nauplii (Inoe, 1965; Jhonson and Knight, 1968; Dexter, 1972). Live or freshly killed chaetognaths, fish larvae, ctenophores and hydromedusae also proved to be excellent food sources (Mitchel, 1971). But the difficulty in obtaining sufficient numbers percludes these as food sources in lengthy laboratory studies (Dexter, 1972). Hence nauplii of *Artemia* remains as one of the best feeds for early larval stages of palinurid larvae.

The present study is intended to estimate the effects of density of *Artemia salina* nauplii on feeding and moulting frequency of phyllosoma larvae of the Indian spiny lobster *Panulirus homarus*.

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MATERIAL AND METHODS

Laboratory hatched phyllosoma larvae of the spiny lobster *Panulirus homarus* were fed on live *Artemia salina* nauplii from the second day after hatching. Majority of the larvae moulted into II stage after eight days. To determine optimum density of *Artemia* nauplii required as food daily, it was necessary to hold the larvae individually and culture them at a series of feeding levels. Experiments were conducted in the field laboratory of the Central Marine Fisheries Research Institute, Kovalam, Tamil Nadu, India.

Healthy II stage larvae were selected and reared individually in transparent plastic containers (capacity 125 ml) containing 60 ml of sea water. They were divided into nine groups, each containing four larvae and were fed on freshly hatched *Artemia salina* nauplii in the following rations : 1, 5, 10, 20, 40, 60, 80 and 100 per day. One of the groups was maintained without feeding to study the effect of starvation.

Artemia nauplii were counted and fed to the respective groups daily in the morning after changing water. Sea water used in the study was filtered through 1μ cartridge filters. Before changing water unfed nauplii of the previous day were removed and counted. Moulting of the larvae was recorded whenever it occurred. The moults were removed and preserved in 5% formalin.

The experiment was conducted in ambient water temperature which ranged from 25.4°C to 30°C with an average of 28.1°C. Salinity of the sea water used varied between 32‰ and 34.5‰. Larvae were kept under natural day light condition which prevailed in the laboratory. The study lasted for 37 days and at the end developmental stages attained by the larvae were recorded.

RESULTS AND DISCUSSION

The number of nauplii consumed by the larvae increased from an average of 0.5 in the group given 1 nauplius to 27.8 in that offered 100 nauplii per day (Fig. 1), showing a positive correlation with density of food ($r= 0.959$, p 0.05). It is also evident from Fig. 1 that the larvae are capable of consuming more than 27.8 nauplii, if they are offered more than 100 nauplii per day.

Efficiency of consumption, measured as percentage of available food consumed, was greatest at lower feeding levels (Fig. 1). The reason is that at lower feeding levels the food supply was insufficient to meet the nutritional requirement of the larvae. Percentage of food consumed decreased gradually from 80 to 27.8 between daily rations of 5 and 100 nauplii. But at the lowest density of 1 nauplii/60 ml per day the percentage consumption was only 50, since the larvae became progressively weaker and were unable to catch the prey on its own effort.

Size increase over time (moulting frequency) and size increase per moult are considered as indices of growth in many crustaceans. In *Carcinus* and some other crustaceans nutrition influences size increase over time by controlling moulting frequency and not size increase per moult (Aiken, 1977). In his study size increase per moult could not be measured as it would result in harming the larvae. Preserved moults also could not be measured accurately and hence moulting frequency is considered as growth.

Under starvation and at the lowest ration of 1 nauplius per day the larvae did not moult at all and survived only for 14 and 17 days

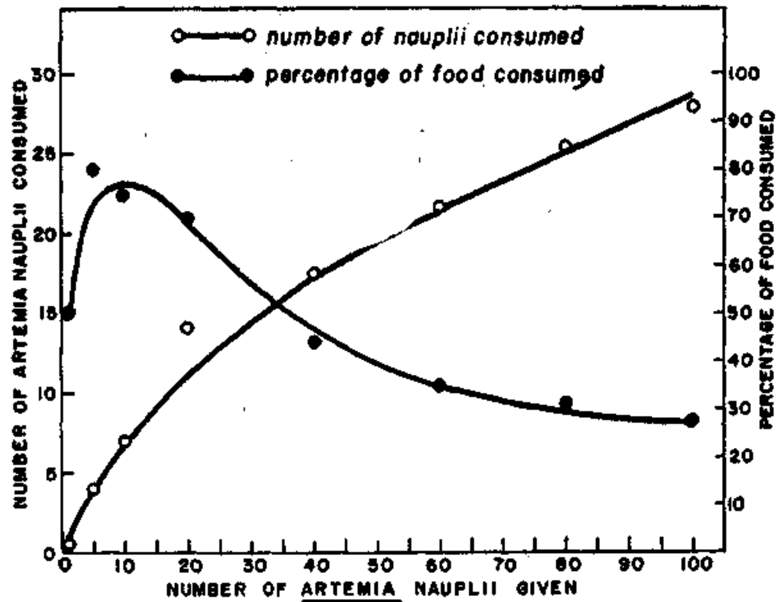

Fig. 1. Number of *Artemia salina* nauplii consumed and percentage consumption in relation to density of nauplii by the phyllosoma larvae of *Panulirus homarus*.

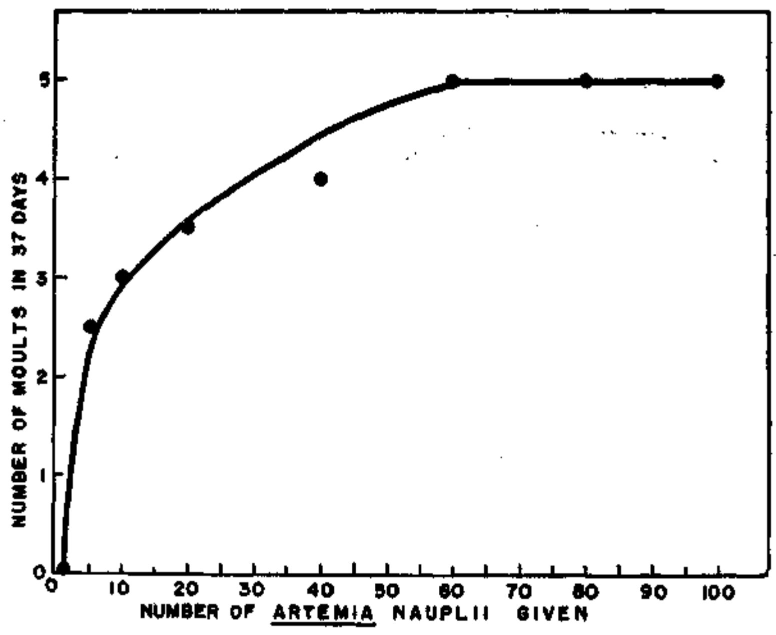

Fig. 2. Moulting frequency of phyllosoma larvae of *Panulirus homarus* in relation to density of food (*Artemia salina* nauplii).

respectively. Starvation and shortage of food resulting in reduced moulting frequency was reported in larvae of the American lobster *Homarus americanus* also by Carlberg and Van Olst (1976). Moulting frequency in *P. homarus* larvae increased from an average of 2.5 when 5 *Artemia* nauplii were offered daily to 5 at a ration of 60 nauplii (Fig. 2) indicating that food availability influences moulting frequency. The same phenomenon has been observed in the phyllosoma larvae of *Panulirus japonicus* by Saisho (1966). He was able to shorten the intermoult period of the first three stages of the phyllosoma of *P. japonicus* by increasing brine shrimp nauplii from 3-5 to 30-40 per ml. Increase in food density from 60 nauplii to 100 eventhough resulted in more consumption did not increase moulting frequency in *P. homarus* larvae. Maximum consumption, therefore, does not indicate maximum growth in phyllosoma larvae of *P. homarus*.

Inoe (1965) suggested that the phyllosoma larvae of *P. japonicus* can be cultured by maintaining 4 brine shrimp nauplii per ml of water, but size of the food should be altered with stage of phyllosoma. Our study indicates that a density of 1 freshly hatched *Artemia salina* nauplius per ml of water is optimum for culturing phyllosoma larvae of *P. homarus* individually since maximum moulting frequency could be attained at a ration of 60 nauplii/60ml of water per day in our experiment. Under this ration the larvae consumed at an average 21.6 nauplii per day. By offering 1.25 freshly hatched *Artemia salina* nauplii per ml to phyllosoma larvae cultured in groups of three, Radhakrishnan and Vijayakumaran (1986) obtained growth rates comparable to the maximum reported here. In their study the larvae consumed only 15.1 ± 0.94 nauplii per day to give this growth rate, indicating that when cultured in groups the larvae consume less and give maximum growth rate.

Total number of moults, the number of days required for each moult and the developmental stage attained by the larvae at the end of the experiment are presented in Table 1. With increase in ration from 5 to 60 nauplii per day

TABLE 1. *Total number of moults, number of days required for each moult and the developmental stage attained after 37 days by II stage phyllosoma larvae* Panulirus homarus *under varying ration of* Artemia salina *nauplii (The larvae took 8 days to reach II stage after one moult)*

Moult	Number of days taken under different ration of nauplii								
	0/day	1/day	5/day	10/day	20/day	40/day	60/day	80/day	100/day
I	—	—	8.5	7	7	6	6	6	6.5
II	—	—	13.5	8	5.5	7	5	5	5.5
III	—	—	8	15	8.5	5	6	6	6
IV	—	—	—	—	12	10	9	8	8.5
V	—	—	—	—	—	—	7	8	7.5
Stage attained after 37 days, by the larvae	Died after 14 days	Died after 17 days	IIIc	IIIc	III c & IV a	IV b	V a	V a	V a

intermoult period decreased from 8.5 to 6 days between the first and second moults; from 13.5 to 5 days between the second and third moults; from 15 to 6 days between third and fourth moults and from 12 to 8 days between fourth and fifth moults. The reduction in intermoult period with increase in density of food suggests that moulting is controlled by the nutritional status of the larvae. Individuals receiving lower rations were only in III c stage or in IV a stage at the end of the experiment (37th day), whereas those receiving higher rations reached V a stage (Table 1). It is observed that at food densities of more than 40 nauplii/60 ml III stage larvae reached IV stage after only two moults, skipping an intermediary moult. At densities lower to this, the larvae required three moults from III to IV stage. Density of food therefore is correlated with speedy development by skipping some of the stages. This finding is supported by the observations of other workers also. Carlberg and Van Olst (1976) opined that in palinurids increased number of larval stages can result from lack of food essential for growth. Robertson (1968) is of the view that other things being equal a well fed larva will be further advanced in the next stage than a poorly fed one.

The study was concluded after 37 days since larvae started dying. Slight reduction in feeding was observed towards the end of the experiment. Many workers (Robertson, 1968; Dexter, 1972) have attributed the reduction in feeding in late larval stages of palinurids to changing nutritional requirements of the larvae. Rearing of palinurid larvae can be carried out with success only if we are able to find out suitable feeds for different larval stages.

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ELECTIVITY AND FOOD RATIONS OF THE FRY OF MILK FISH *CHANOS CHANOS* (FORSKAL) UNDER LABORATORY CONDITIONS

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ABSTRACT

The fry of milk fish *Chanos chanos* (Forskal), measuring 11-15 mm (13.5 mm mean length) obtained from the creeks and canals of Puthuvype area in the Vypeen Island have been used to study the electivity and food rations under laboratory conditions using rotifers, copepods, copepodites, copepod nauplii and *Artemia* nauplii as feed. The observations at 24 hour intervals lasted for 7 days in one set and 14 days in another set of experiments in different containers with 10‰ salinity. The survival rate was 100% during the period of observation.

The index of electivity varied between —0.7839 to +0.0575 for roitifers, —0.0034 to +0.4598 for copepod nauplii and —1.0 to +0.0509 for copepodites and copepods, showing first preference towards copepod nauplii and then to rotifers and copepodites and copepods. The quantitative relations between food concentration and rate of feeding have been discussed.

INTRODUCTION

FOOD AND FEEDING is an important factor in the early life history and the survival of fry depends on the availability of the right kind of food.

Three methods have been employed to study the feeding of larval fishes. In the first method, as followed by Lebour (1918, 1919 a, b), Sarojini (1954), Berner (1959) and Covill (1959), the fish larvae are collected from the natural waters and the food organisms present in their guts are studied. In the second method, as followed by Marshall *et al.* (1937), Yokota *et al.* (1961) and Blaxter (1965), the fish larvae and the plankton are collected from the natural waters and the gut contents are compared to the availability of plankters in the natural waters so as to determine the selective feeding. In the third method, as followed by Blaxter (1968), Rosenthal (1969) and Ghosh and Das (1972) the fish larvae are reared and provided with different food organisms and the gut contents are compared with the food organisms present in the tank or by counting the left over food organisms and thereby determining the food consumption and the type of food.

The rearing of the fry and fingerlings of milkfish *Chanos chanos* (Forskal), using zooplankters has been discussed by Alikunhi *et al.* (1976); Chaudhuri *et al.* (1978); Ranoemihardjo *et al.* (1975); Yamasaki and Canto (1978) and Yamasaki (1977). However, there is a lack of information on the electivity and food rations of milkfish fry following the principles of Parsons and Le Brasseur (1970) and Sushchenya (1970).

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Material and Methods

The milkfish fry, used in this experiment were collected from the creeks and canals of Puthuvype area in the Vypeen Island, in waters with 9‰ salinity. The body length ranged from 11 to 15 mm with a mean of 13.5 mm. The mean weight was 7.04 mg.

The milkfish fry were kept for 24 hours in zooplankton enriched water with 10‰ salinity, before distributing to different experimental containers. A combination of rotifers *Brachionus urceolaris* and copepods, copepodites and copepod nauplii of *Pseudodiaptomus annandalei* were made in different proportions and kept in quadruplicate in 1 litre beakers with 3 milkfish fry in each for preliminary screening and in duplicate in 3' dia pools with 100 litre of 10‰ water with 100 milkfish fry in each for field studies. The rotifers and copepods were obtained from different mass culture tanks maintained under controlled conditions. The total food organisms varied between 35,000 to 89,000 per litre, with rotifers ranging from 5,000 to 60,000 per litre, copepod nauplii 3,500 to 59,000 per litre and copepods and copepodites 500 to 38,000 per litre in one litre containers and in the 3' dia pools.

Artemia nauplii were fed in the proportion 200, 400, 800 and 1,000 in the 1 litre beakers and 200 per litre and 1,000 per litre in the 3' dia. pools. *Artemia nauplii* were not mixed with rotifers and copepods, copepodites and copepod nauplii. The *Artemia* nauplii were used to understand the growth rate between the fry fed with rotifer and copepod combination and *Artemia* nauplii. Counts were made for every 24 hours and fresh nauplii were introduced to make up the original number. Controls were kept and observed every 24 hours. The experiments were of 7 days duration in 1 litre beakers and 14 days in 3' dia pools with 100 l water.

To study the electivity, the formula as proposed by Ivlev (1961) and discussed by Parsons and Le Brasseur (1970) has been used.

$$\text{Electivity index (E)} = \frac{ri - pi}{ri + pi}$$

where 'ri' is a relative count of different organisms consumed and 'pi' is a relative count of different organisms present in the surrounding water.

The relation between food ration (consumption) and food concentration has been studied by using the formula as proposed by Sushchenya (1972). At high food concentration R=Rmx. Rmx=the asymptotic relation between ration and food concentration as ration tends to its maximum.

Relation between rations value (R) and food concentration (K) has been calculated using the formula :

$$R = Rmx\,(1 - 10^{-pk})$$

where 'p' is estimated by least squares.

That is

$$p = \frac{1}{n} \sum_{I=1}^{n} \frac{\log Rmx - \log (Rmx - Ri)}{Ki}$$

Results

Electivity

The electivity index are presented in Table 1 for the experiments conducted in one litre containers and in Table 2 for experiments conducted in 3' dia pools. The electivity index varied between —0.7839 to +0.0575 for rotifers (size 153 to 272 μ); —0.0051 to + 0.4598 for copepod nauplii (size 119 to 225 μ) and —1.0 to +0.0509 for copepods and copepodites (size 510 to 1190 μ). For rotifers,

TABLE 1

Expt. No.		Rotifers			Copepod nauplii			Copepods and copepodites		
		Relative concentration		Electivity Index Number	Relative concentration		Electivity Index Number	Relative concentration		Electivity Index Number
		% in Water	% Consumption		% in Water	% Consumption		% in Water	% Consumption	
I	A.	60.76	47.06	—0.1271	36.71	50.94	0.1623	2.53	2.00	—0.1169
	B.	66.67	21.05	—0.5201	27.27	73.69	0.4598	6.06	5.26	—0.0706
	C.	55.0	6.66	—0.7839	20.00	85.00	0.4285	25.00	8.34	—0.4997
	D.	40.0	8.00	—0.6666	30.00	78.00	0.4444	30.00	14.0	—0.3636
II	A.	76.71	76.92	0.0014	17.81	19.99	0.0577	5.48	3.08	—0.2804
	B.	85.11	88.41	0.0191	8.51	11.59	0.3049	6.38	0	—1.0
	C.	84.0	85.11	0.0066	14.0	14.89	0.0308	2.0	0	—1.0
	D.	77.77	81.35	0.0224	20.83	18.65	—0.0552	1.39	0	—1.0
III	A.	77.46	67.75	—0.0669	20.46	31.01	0.2090	2.08	1.24	—0.0669
	B.	80.32	77.49	—0.0052	17.46	20.77	0.0866	2.22	1.74	—0.1244
	C.	77.74	77.74	0	20.19	20.19	0	2.07	2.07	0
	D.	79.67	76.45	—0.0206	18.50	23.55	0.1201	1.83	0	—1.0
IV	A.	49.16	48.76	—0.0041	49.16	59.12	0.0096	1.68	1.12	—0.2
	B.	36.10	34.62	—0.0209	62.62	65.38	0.0220	1.28	0	—1.0
	C.	24.85	24.84	—0.0002	74.53	74.54	0.0001	0.62	0.62	0
	D.	37.81	37.81	—	59.70	59.70	0	2.49	2.49	0
V	A.	21.85	20.63	—0.0288	74.81	75.80	0.006	3.34	3.57	0.0333
	B.	22.2	25.00	0.0563	33.0	63.0	0.3125	44.8	12.00	—0.5774
	C.	32.5	33.5	0.0151	30.0	52.0	0.2682	37.5	14.5	—0.4423
	D.	36.8	38.2	0.0186	28.9	50.6	0.2729	34.3	11.26	—0.5076
VI	A.	65.15	68.97	0.0291	32.57	30.01	—0.0409	2.28	1.02	—0.3818
	B.	65.15	70.89	0.0422	32.57	28.72	—0.0628	2.28	0.39	—0.7078
	C.	65.15	66.51	0.0103	32.57	31.16	—0.0221	2.28	2.33	—0.0108
	D.	65.15	69.93	0.0353	32.57	29.95	—0.0419	2.28	0.12	—0.9
VII	A.	32.32	32.31	0.0058	64.63	64.08	—0.0043	3.65	3.21	0.0256
	B.	32.0	34.36	0.0356	63.23	61.22	—0.0160	4.77	4.42	—0.0350
	C.	31.86	31.86	0	66.23	66.23	0	1.91	1.91	0
	D.	33.68	33.68	0	65.26	65.26	0	1.06	1.06	0

TABLE 2

Expt. No.		Rotifers			Copepod nauplii			Copepods and copepodites		
		Relative concentration		Electivity Index Number	Relative concentration		Electivity Index Number	Relative concentration		Electivity Index Number
		% in Water	% Consumption		% in Water	% Consumption		% in Water	% Consumption	
I	A.	74.61	75.10	0.0033	17.63	16.72	—0.0265	7.76	8.18	0.0263
	B.	65.52	65.44	—0.0006	17.24	18.43	0.0334	17.24	16.13	—0.0333
II	A.	70.39	71.29	0.0064	27.39	26.89	—0.0109	2.22	1.91	—0.0751
	B.	38.09	33.19	—0.0696	59.25	66.26	0.0559	2.66	0.61	—0.6269
III	A.	65.47	65.87	0.0030	33.82	34.13	0.0046	0.71	0	0
	B.	28.12	27.36	0.0137	68.79	69.09	0.0022	3.09	3.55	0 0503
IV	A.	62.85	66.98	0.0518	33.89	29.41	—0.0708	3.26	3.61	0.0509
	B.	30.68	32.36	0.0219	67.91	66.15	0.0131	1.41	1.49	0.0311
V	A.	67.09	73.51	0.0457	29.42	24.57	—0.0898	3.49	1.92	—0.2902
	B.	63.31	63.03	—0.0022	31.45	34.13	0.0409	5.24	2.84	—0.2985
VI	A.	51.72	51.79	0.0007	44.83	46.43	0.0175	3.45	1.78	—0.3193
	B.	40.58	42.42	0.0222	57.97	57.58	—0.0034	1.45	0	—1.0
VII	A.	51.61	50.00	—0.0158	45.16	48.28	0.0334	3.23	1.72	—0.3051
	B.	41.67	44.44	0.0322	57.29	55.56	—0.0153	1.04	0	—1.0
VIII	A.	52.63	51.85	—0.0075	45.61	48.15	0.0271	1.76	0	—1.0
	B.	46.15	45.63	0.0052	51.28	51.81	0.0051	2.57	1.56	—0.2446
IX	A.	90.09	89.57	—0.0029	9.01	9.48	0.0254	0.90	0.95	0.0270
	B.	91.56	90.51	—0.0057	7.75	8.81	0.0640	0.59	0.68	0.0708
X	A.	17.39	19.25	0.0508	73.91	76.47	0.0170	8.60	4.28	—0.3405
	B.	17.39	19.51	0.0575	73.91	78.95	0.0272	8.70	2.42	—0.5619
XI	A.	55.06	51.77	—0.0307	29.56	32.63	0.0494	15.38	15.60	0.0071
	B.	46.51	44.61	—0.0208	41.86	46.81	0.0558	11.63	8.58	—0.1509
XII	A.	74.01	73.21	—0.0054	25.82	26.61	0.0151	0.17	0.18	0.0285
	B.	72.88	72.88	0	25.42	25.42	0	1.70	1.70	0
XIII	A.	49.50	48.15	—0.0138	49.51	50.83	0.0132	0.99	1.02	0.0149
	B.	46.51	47.62	0.0118	51.16	50.00	—0.0115	2.33	2.38	0.0106

though there is a slight shift of values from negative to positive during the course of experiment, there is not much shift observed in the values obtained from 3' dia pools. More positive values obtained for copepod nauplii indicate the preference for these organisms. Electrivity index values were more negative for copepodites and copepods.

Ration

There is a relation between rations value and food concentration (Fig. 1). As the food concentration increased, there was a progressive drop of consumption resulting in an asymptotic relation between ration and food concentration (Fig. 1). The maximum ration of 18,000 prey/fish/day was obtained for rotifers

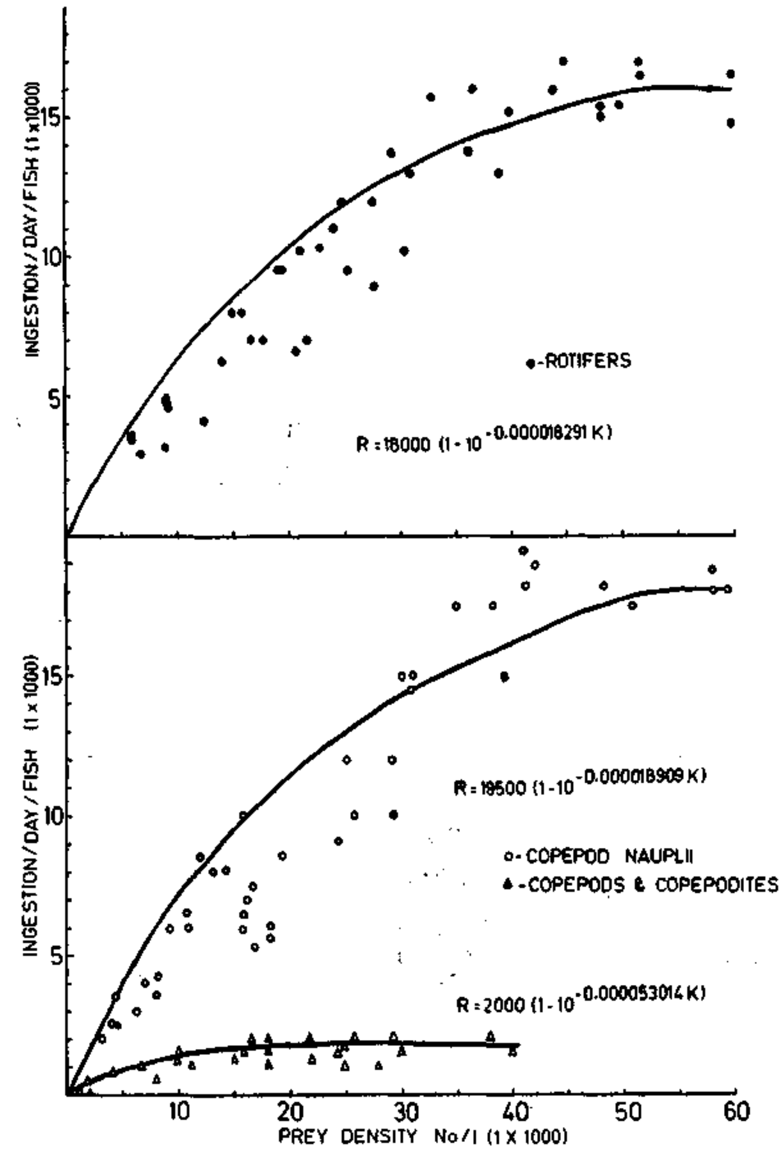

FIG. 1. Relation between rations value and food concentration.

when the prey concentration was around 40,000 per litre, the ration tend to decrease above this prey density.

The ration maximum (Rmx) reached 19,500 for copepod nauplii when the prey concentration was around 42,000 per litre. However, the ration reduced to about 18,000 copepod nauplii/fish/day above this prey density. The ration values for copepods and copepodites were low compared to rotifers and copeod nauplii and also showed high negative electivity index. Even at 40,000 per litre prey density, the ration maximum (Rmx) was only around 2,000 copepod and copepodites/fish/day. The Rmx reached at about 23,000 per litre prey density and then onwards the curve is almost parallel to the axis.

Growth rate

Data on the body length and weight of milkfish fry has been summarised in Table 3. During the experiment, the maximum mean growth rate of 0.8928 mm/day has been achieved for the fry fed with 61092.2 prey density rotifer and copepod combination. There is an increase of growth rate with the increase of prey density as it is shown in experiment A (conducted in one litre beakers) and B (conducted in 3' dia. pools). The maximum increase in weight was 7.4143 mg per day for the fry in the container with 61,092.2 prey density of rotifers and copepod combination. However, not much change in the growth rate (0.8214 mm/day or 6.6571 mg/day) was observed in the fry fed with 72353.8 prey density of the above combination.

In the experiments fed with *Artemia* nauplii the growth rate was less compared to fry fed with rotifer and copepod combination. The maximum growth rate of 0.7743 mm/day (weight 7.1429 mg per day) was achieved for the fry in the container with 1,000 per litre *Artemia* nauplii. This is next to the growth rate of 0.8928 mm per day (weight 7.4143 mg per day) for the fry fed with 61.092.2 per litre of rotifer and copepod combination.

Discussion

Schuster (1960) observed that the 13 to 18 mm larvae of milkfish feed on epiphytic planktonic organisms, the principal share of food organisms being diatoms. Chacko (1949) investigated the young stages of estuarine fishes in the waters of Madras and opined that *Chanos chanos* are almost entirely plankton feeders. Utilization of zooplankters as feed for *Chanos* fry has already been evidenced by Alikunhi *et al.* (1975), Chaudhuri *et al.* (1978) and Yamasaki and Canto Jr. (1978).

During the present investigation an attempt has been made to understand the selection and utilization of zooplankters, such as rotifers and copepods, as food by the milkfish fry. The electivity index shows that the fry prefers copepod nauplii to rotifers or in par with it. This may be related to the prey size of rotifers (153 to 272 μ) and copepod nauplii (119 to 225 μ). This may also be related to the observation by Detwyler and Houde (1970) that for both clupeid and engraulid larvae the limiting factor for food size is the gape of the jaw, not the length of the gut. The copepods and copepodites being larger in size, the *Chanos* fry showed more negative index values. The motility of the food organism must also be considered, wherein copepod nauplii are less motile than copepodites and adult copepods. Liao *et al.* (1971) opined that the quality, size, density and mobility of the food are the important factors for developing larval rearing techniques.

An attempt has also been made to understand the food ration of *Chanos* fry. Parsons and Le Brasseur (1970) opined that the quantity grazed by a predator, indicate that the quantity of food consumed is concentration dependent and can be best explained by a relationship

TABLE 3

Expt. No.	Group diet	Food density/ 1/day	Initial length mm		Final length mm		Mean growth		Mean initial weight	Mean final weight (mg)	Weight fish gained (mg)	
			Range	Mean	Range	Mean	7 days	Per day			7 days	per day
A 1	Rotifers copepod nauplii copepods—& copepodite ..	72,353.8	12-15	13.25	18-20	19.0	5.75	0.8214	8.4	55.0	46.6	6.6571
2	Do. ..	61,092.2	12-15	13.25	19-20	19.5	6.25	0.8928	8.4	60.3	51.9	7.4143
3	Do. ..	38,957.14	11-13	12.00	16-18	17.0	5.0	0.7143	6.2	41.0	34.8	4.9714
4	Do. ..	46,192.8	12-15	13.25	18-20	19.0	5.75	0.8214	8.5	55.4	46.9	6.7
5	Artemia nauplii ..	200	11-14	12.50	16-18	17.33	4.83	0.69	6.4	39.9	33.5	4.7857
6	Do. ..	400	11-14	12.85	17-18	17.33	5.08	0.7257	6.4	39.9	36.5	5.2143
7	Do. ..	800	12-15	13.25	17-20	18.60	5.35	0.7643	8.3	56.1	47.8	6.8285
8	Do. ..	1,000	11-14	12.25	17-18	17.67	5.42	0.7743	6.5	56.5	50.0	7.1429
											14 days	
B 1	Rotifers copepod nauplii copepods—& copepodites ..	37,706.2	11-13	12.00	19.26	22.06	10.06	0.7738	6.25	79.4	73.15	5.6269
2	Do. ..	21,442.3	11-14	12.25	17-26	20.466	8.216	0.632	6.50	67.4	60.9	4.6846
3	Artemia nauplii ..	200	11-13	12.00	16-19	17.733	5.733	0.441	6.25	40.3	34.05	2.6192
4	Do. ..	1,000	11-13	12.50	19-28	21.466	8.966	0.6896	6.50	73.1	66.6	5.1231

similar to that proposed by Ivlev (1945) for planktivorous fish. In considering this problem for fishes Ivlev (1955) found that as food concentration increased, the increased ration was less than expected, suggesting a progressive drop in grazing efficiency, this was confirmed during the present investigation. The maximum ration was 18,000 rotifers per day per fry; 19,500 copepod nauplii per day per fry and 2,000 copepods and copepodites per day per fry, when the prey density was at or above 40,000 per litre.

Ghosh and Das (1972) observed that mullet fry (*Mugil parsia* Hamilton) of 12-20 mm size groups conssumed upto 17,500 rotifers within 24 hours. Theilacker and McMaster (1971) observed that best growth rates for larval anchovy *Engraulis mordax* were obtained in the high food density experiments, when 10-20 rotifers per ml were fed. It is observed that a high food denisty should be maintained for the fish larvae feeding on rotifers. During the present investigation the maximum ration of 18,000 rotifers per day per fish and 19,500 copepod nauplii per day per fish are comparable to the values obtained by Ghosh and Das (1972) for *Mugil parsia* (12 to 20 mm size). The increased ration may also be related to the high prey density provided in the experimental containers compared to the prey density available in the natural environment. The maximum ration of only 2,000 copepodites and copepods may be related to the large size and motility of the food organism, which results in negative electivity.

The growth rate indicates that there is no significant difference between the fry fed with rotifer and copepods and *Artemia* nauplii. Maximum growth rate of 0.8928 mm per day was obtained for fry fed with rotifer and copepod combination and 0.7743 mm per day obtained for the fry fed with *Artemia* nauplii. However, the prey concentration of *Artemia* was considerably lower than that of the rotifer and copepod combination.

Yamasaki and Canto Jr. (1978) observed that no significant difference of growth of *Chanos* fry was found between fishes fed with *Tisbe* and *Artemia*. Further they opined that harpacticoid copepod *Tisbe* sp., shows potential as a substitute to the more expensive *Artemia* or to *Brachionus* which is used as food for finfish and crustaceans secondary to *Artemia*.

Raleanal *et al.* (1952) stocked 12.9 mm (5 mg) fry in fish pond nurseries and obtained 52.4 mm (1.42 gms) in 8 weeks. Alikunhi *et al.* (1975) stocked 11 to 14 mm *Chanos* fry in manured pools for the production of rotifers and obtained 67 to 98% survival rate. Schuster (1952) obtained 122 mm (30 gms) growth from 13 mm (0.01 gm) fry within 8 weeks in brackishwater ponds of Java. The maximum growth rate observed (Schuster, 1960) in nursery ponds was 1.9464 mm per day for *Chanos* fry, whereas in the present investigation it was 0.8928 mm per day for the fry fed with rotifer and copepod combination at 61092.2 per litre prey density. The stage of fish larvae and the ecosystem existing in the culture tank also should be considered for evaluating the growth rate.

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OXYGEN CONSUMPTION OF THE YOUNG RIDLEY TURTLE *LEPIDOCHELYS OLIVACEA* (ESCHSCHOLTZ)

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Abstract

The metabolic rates (oxygen consumption) and corresponding activity were studied in young turtle of the species *Lepidochelys olivacea* (Eschscholtz). Experiments were also conducted to study the influence of ambient oxygen on activity and oxygen consumption. The turtles of the size group between 67 and 95 mm in carapace length (curved) were acclimated and tested at an average temperature of 30°C and 30.37‰ salinity.

Immediately after handling, the metabolic rates and corresponding activity were found to be high as 1110.13 mg/kg/hour and 24 L/15 min. The asphyxial oxygen level ranged between 4.15 and 4.84 mg/l.

Introduction

Though the physiology dealing with several aspects such as metabolism, metabolic adaptations, temperature tolerance and resistance, influence of various environmental factors has been extensively studied in the case of fishes, prawns and intertidal mollsucs, no information on the metabolism of young ridley turtles is available. In the present study, experiments have been conducted in the same manner described earlier (Ameer Hamsa and Kutty, 1972) on the oxygen consumption and corresponding activity of young ridley turtle of the species *Lepidochelys olivacea*. The influence of ambient oxygen on activity and oxygen consumption has also been investigated.

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Material and Methods

During the course of conducting surveys to locate the turtle nests around the Islands in the Gulf of Mannar region, a total of 572 eggs of *Lepidochelys olivacea* were collected from four nests along the shore near Hare Island during October-November, 1977. The eggs were buried in the sand beyond the shoreline and the area was enclosed by wooden reepers in order to keep the eggs safe. Only 91 baby turtles (42-47 mm in carapace length) had come out from the enclosed nest after 58 to 64 days. Though the hatching was poor (15.9%), the hatched ones were healthy in aquarium conditions. The young turtles were kept in running sea-water in circular polycraft pools (diameter : 90 cm ; depth ; 60 cm) and were acclimatized to the laboratory conditions (Pl. I A). They were daily fed with minced fish meat and fragments of fresh seaweed (*Gracilaria* spp.). They attained the mean size of 80 mm in carapace length (curved) after 5 months and specimens measuring between 67 and 95 mm in carapace length are used in this study (Pl. I B). Temperature of the water in the acclimation tanks was about 30°C and salinity about 30.37‰. Dissolved oxygen at 80-96% air saturation. The experiments were conducted at acclimation conditions.

The experiments were conducted using a 'metabolism chamber' (Pl. I C) (Ameer Hamsa and Kutty, 1972) inside which Fry's annular respirometer (Fry and Hart, 1948; Ameer Hamsa and Kutty, 1972) of transparent hard plastic (outer diameter: 30 cm; inner diameter: 11 cm; height: 20 cm; capacity: 12.5 litres) was kept.

The experimental turtle was separated from the stock and kept in a circular polythene trough (diameter: 60 cm; depth: 26 cm) in running sea-water without giving food. After 24 hours, the live turtle was taken out and noted the carapace length and weight were noted, and then transferred immediately to the Fry's respirometer for experiment (Pl. I D). Three measurements of metabolism were made within one and quarter hours after introducing the turtle in the respirometer. Initial water sample was drawn out from the respirometer and the first measurement (run) was made by closing the respirometer for the first quarter hour. The turtle was allowed to consume the dissolved oxygen content available in the water inside the respirometer. At the end of first quarter water sample was taken for oxygen determination. This was followed by a flushing interval of 15 minutes. Then a second set of water samples were collected at the beginning as well as the end of third quarter hour. The flow through the respirometer was resumed again. This sampling procedure was continued till the completion of third measurement. The lid of the metabolism chamber was partially kept open (Pl. I C). During the runs, visual counts of the number of times the turtle went round in the annular chamber were made in alternate period of 3 minutes. From these values an estimation of spontaneous activity during the sampling period of 15 minutes (run) was obtained. The metabolic rate of the turtle was also estimated from the values of dissolved oxygen concentrations of the initial and final samples of each measurement. The turtle was weighed again at the end of the experiment.

In the experiments where the influence of ambient oxygen was studied, the turtle starved for 24 hours was directly transferred from the circular polythene trough to the respirometer after noting its carapace length and weight. The turtle was allowed to reduce the dissolved oxygen content in the respirometer and during the experiment water samples were drawn out from the respirometer at the interwal of every quarter hour (run) until the turtle attained the critical stage (asphyxial level). In this case the flushing through the respirometer was stopped between each measurement of metabolism. Metabolic rate was calculated from the dissolved oxygen concentrations in the water; simultaneously corresponding activity was also estimated for each measurement. Dissolved oxygen concentrations were measured by using standard Winkler's method.

Results and Discussion

The results obtained from five experiments on turtles of similar size are presented in Table 1. The values of initial (first measurement) oxygen consumption and activity are the rates of metabolism and spontaneous activity obtained immediately after handling. The initial rates of metabolism and activity are invariably higher than that of the subsequent rates. In all the experiments oxygen consumption decreased with a decrease in the corresponding activity after the first measurement. It has been observed that in all the cases where the metabolic rates immediately after handling were high the activity rates were also high

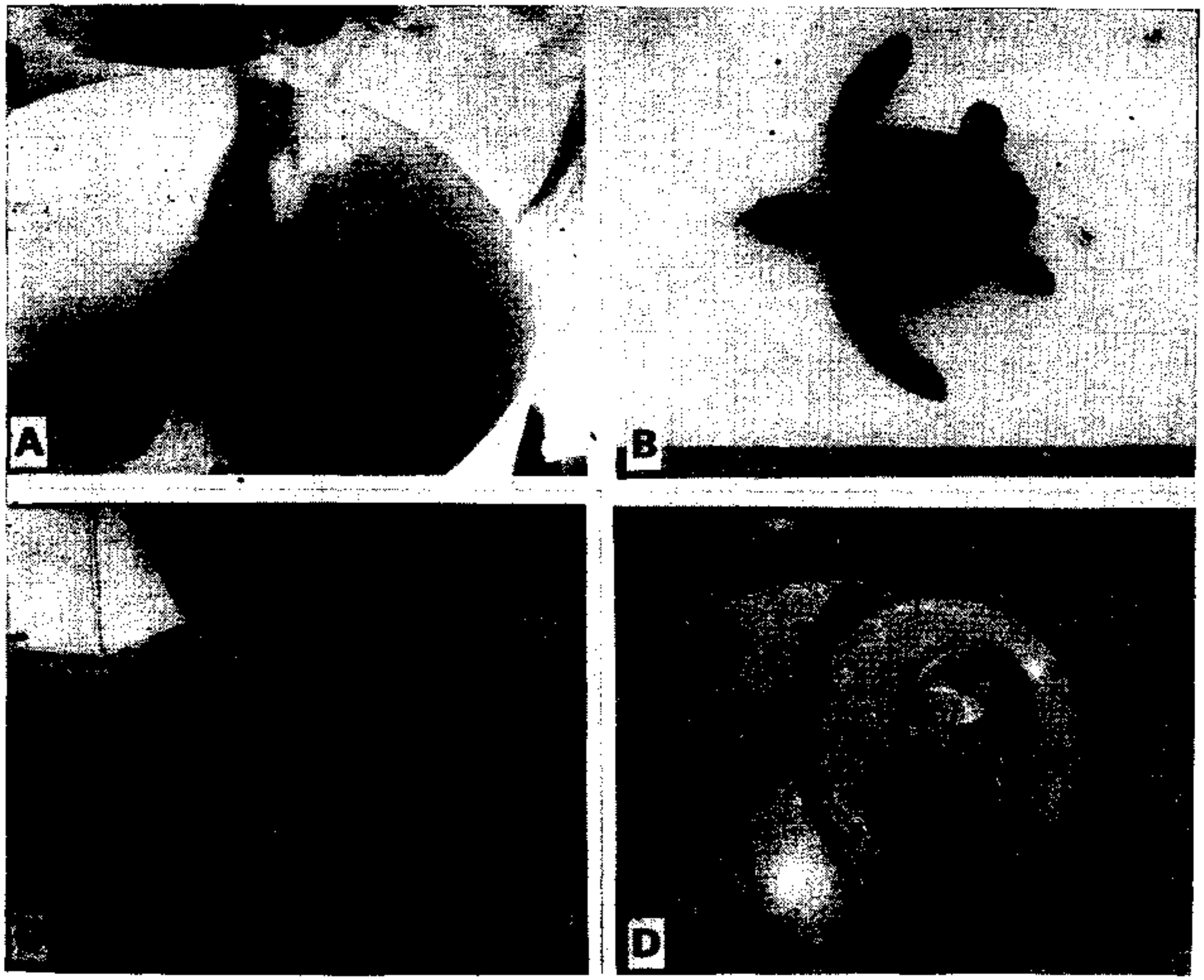

PLATE I A. Baby turtles of *Lepidochelys olivacea* in the acclimation tanks; B. Close-up view of a baby turtle; C. View of wooden metabolism chamber with lid in partially open condition and D. View of Fry's respirometer kept inside the wooden metabolism chamber under water. Note a turtle in the respiration chamber.

TABLE 1. *Oxygen consumption and corresponding activity of ridley turtle* Lepidochelys olivacea. (*The turtles were acclimated and tested in seawater at an average temperature of* 30°C *and* 30.37‰ *S*)

	Experiments				
	1	2	3	4	5
Carapace length (Curved mm) ..	77	67	76	73	77
Weight (g) ...	74	51	73	69	73
Oxygen consumption ..	1110.13	339.02	355.27	626.54	118.42
(mg/kg/hr)	1051.35	339.02	355.27	501.44	118.42
Mean in parentheses ..	116.82	169.51	236.85	387.25	0.00
	(759.43)	(282.51)	(315.79)	(505.04)	(78.94)
Spontaneous activity — ..	3.475	24.00	6.99	4.763	8.405
L/15 min.	1.379	Nil	3.521	1.099	Nil
Mean in parantheses ..	0.350	2.019	0.699	0.370	Nil
	(1.401)	(8.650)	(3.736)	(2.077)	(2.801)

The first value in each experiment is considered as the value obtained immediately after handling.

TABLE 2. *Ambient and asphyxial level of oxygen in the experiments conducted with young ridley turtle* Lepidochelys olivacea. (*The turtles were held and tested in seawater at* 30°C *and* 30.37‰ *S*)

Experiments	Activity (L/15 min.)	Oxygen consumption (mg/l) Initial	Oxygen consumption (mg/l) Final (Asphyxial level)	Ambient Oxygen (mg/l)	Carapace length (mm) (and weight in g) of turtle tested
1	13.850	4.812	4.322	4.567	83
	4.539	4.322	4.322	4.322	(99.5)
	5.493	4.322	4.322	4.322	
	3.549	4.322	4.322	4.322	
2	Nil	4.495	4.322	4.408	87
	9.548	4.322	4.322	4.322	(101.5)
	2.443	4.332	4.322	4.322	
	0.31	4.322	4.322	4.322	
3	Nil	4.322	4.1498	4.2359	83
	4.841	4.1498	4.1498	4.1498	(88.5)
	8.380	4.1498	4.1498	4.1498	
	1.279	4.1498	4.1498	4.1498	
4	6.202	5.0143	4.841	4.9276	95
	13.015	4.841	4.841	4.841	(122.5)
	1.424	4.841	4.841	4.841	
	0.38	4.841	4.841	4.841	

(Ameer Hamsa and Kutty, 1972). From Table 1 it is clear that there is a direct correlation between activity and metabolic rate inspite of the high variability between animals.

The values of ambient and asphyxial level of oxygen are given in Table 2. In all the experiments oxygen consumption was observed only during the first measurement of metabolism (1st 15 minutes run) and the turtles did not consume oxygen afterwards. The consumption of oxygen was also less (0.173 mg/1) in 3 out of 4 experiments eventhough the ambient oxygen level was sufficiently high. The asphyxial level of oxygen ranged between 4.15 and 4.84 mg/1 and this level seemed to be high when compared to the values (0.62-1.50 mg/l) obtained for fishes.

Although the data is limited, the available information on the oxygen consumption and activity of turtles may be the first of its kind from Indian waters and may also be of much use to those who are in this field of study.

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ECOLOGY OF *ALITROPUS TYPUS* M. EDWARDS (ISOPODA, FLABELLIFERA, AEGIDAE) IN RELATION TO AQUACULTURE

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ABSTRACT

Alitropus typus, the fresh water isopod, occurs in tropical South-east Asia. In India, it occurs abundantly in the fresh and slightly brackish water tracts along the southwest coastal regions. The juveniles of this species cause immense damage to the fishes living in these habitats by leading a parasitic life on their gills, buccal cavity or opercular regions and sucking the blood from the host with the help of the piercing type of mouth parts. As adults, however, they lead a free-swimming life. The adults aswell as the young ones of this species have the remarkable ability to withstand considerable variations in the salinity and temperature of the medium in which they live, even though embryonic development is severely curtailed in higher saline media. Thus the breeding females have to restrict themselves to fresh water for the normal development of the young inside the brood pouch. Taking into consideration the importance of this species in the field of aquaculture, studies were initiated to understand the breeding biology, ecology and the nature of damage it causes to the fishes. These animals show clear sexual dimorphism and breeding occurs throughout the year with a slight cessation during the months of April, July and November. Studies on the sex ratio showed a preponderance of females during most of the months studied. Development of the eggs and embryos takes place within the brood pouch and the incubation period is about 42 days. The young ones when released from the marsupium begin to attack the fishes in the neighbourhood and feed on the blood and mucus. Their growth is severely retarded, if they are deprived of the nourishment from the hosts. They can cause severe haemorrhage while sucking the blood and the secondary infection of the hosts through the wounds they inflict can prove fatal. Owing to the infestation of these parasites, the hosts suffer serious depletion of major organic constituents such as glycogen, lipids and protein and through loss of blood they become anaemic which is macrocytic-hypochromic in nature. Studies on the peripheral white blood cells of the infested fish show that leucopenia together with lymphocytosis occur as a result of the attack of these parasites. Thus the control of these parasites in the nurseries and ponds is highly desirable for achieving success in fish culture. The possibility of chemical control of these parasites by the application of very low doses of organophosphate compounds has been tried and found to be quite successful. Of the different biocides tried, Folithion, Hinosan and Malathion were found to be very effective in controlling these parasites and the dose applied to kill them was found to be harmless to the fishes of the habitat.

INTRODUCTION

STUDIES on the crustacean parasites which are harmful to fishes have hitherto been sporadic and inadequate. Although knowledge of certain crustacean parasites — particularly those of copepods — on fishes has progressed rapidly in the past few decades, little incentive has existed for a complete and comparable understanding on the role of these parasites on fishes. As members of malacostraca, the isopod parasites are numbered among the higher crustacea and with certain exceptions, they do not undergo major morphological changes upon becoming parasites. A recent estimate of the total number of species of parasitic isopods is about 430 (Kabata, 1970), but this number will be really higher since very little information is available from tropical and sub-tropical regions. Majority of these isopods are blood feeders and are known to cause serious damage to the fishing industry. The changes that are caused in the muscle tissues of the host fishes through parasitization are the mechanical damage resulting from the feeding and the ensuing secondary infections (Kabata, 1970).

Reviewing the literature, one can find that a good amount of work has been done on the taxonomy and distribution of these animals. In India, works on the parasitic isopods are mainly contained in the published works of Chopra (1923, 1930) and pillai (1963, 1964, 1967). A detailed account on the effect of attack is given by Akhmerov (1939), Field (1969), Briggs (1970), Kroger and Guthrie (1972), Lanzing and O'Connor (1975), Lindsay and Moran (1976) and Romestand and Trilles (1977).

The present investigation primarily deals with the biology and ecology of *Alitropus typus* M. Edwards which is a common species found along the southwest coast of India. It is a member of the family Aegidae, sub-order Flabellifera and order Isopoda. They are very fast swimmers and the juveniles are ectoparasites clinging on the gills, buccal cavity and opercular regions as well on the body surfaces of various fishes and feeding on their blood and mucus. As adults, however, they are free-living and show clear sexual dimorphism. Despite its wide-spread occurrence in the fresh and slightly brackish water tracts, there has been no detailed information on their ecology and hence an attempt has been made to study the same. Studies were conducted with a view to understanding the effect of attack of these parasites on various fishes, factors which influence their activities, their breeding biology and the control measures to be taken to check the juveniles of the species.

One of us (G.A.N.) is grateful to C.S.I.R. for awarding the Senior Research Fellowship during the tenure of which this work was carried out.

Material and Methods

Sampling of *A. typus* population was done from January 1977 to December 1978 at regular intervals from 5 different sites selected along the edges of the eutrophic Museum pond, Trivandrum, Kerala. Each site has an area of $3 \times 3 \times 1$ m^3. The isopods were picked in fair numbers from each site by using a net and also from beneath the laterite stones submerged in the water, keeping 30 minutes time as a constant factor. Whenever necessary, nets were also hauled to catch the fishes found in the pond to examine their gills and opercular regions for any juveniles of the species.

The sampled animals were preserved in buffered 5% formalin and were later examined under a binocular microscope to check the secondary sexual characters. Length measurements of all sampled animals were taken along the median axis from the front of the cephalon to the posterior border of the telson. The primary sex characters were noted by dissecting the individuals under a stereomicroscope. Based on the above mentioned observations made, each sampled individual was assigned to one of the following classes, *viz.* (1) juveniles (2) males (3) females and (4) ovigerous females. For several hundred individuals of the species examined, the minimum size of juveniles upon release from the marsupium was 3.5 mm in body length. Males are recognizable at 9 mm and females at 10 mm body length.

The following biochemical methods were adopted. Protein was estimated by the Microkjeldahl method (Wong, 1923) as described by Hawk *et al.* (1954). The Anthrone reagent method (Seifter *et al.*, 1950) was employed for the estimation of Glycogen and the Chloroform-ethanol method described by Heath and

Barnes (1970) was used for the estimation of lipids.

The haematological parameters of the infested and non-infested fishes of *Channa striatus* (Bloch) were studied following the methods given by Kolmer *et al.* (1969).

The static bioassay procedure outlined by Doudroff *et al.* (1951) with some modifications in regard to general techniques to suit the objectives of the present investigations were employed for the estimation of LD_{50} values of different biocides used against the juvenile *A. typus*.

Observation and Results

Factors influencing the activity of A. Typus

A. typus is a very active animal which can tolerate the variations of temperature and salinity to a great extent. The temperature and salinity of the pond water from where these animals were sampled usually ranged from 25 to 29°C (and is never below 23°C) and 0.5‰ to 1.7‰ respectively and both these factors are very well within their tolerance limits. Oxygen and food were never limiting.

Effect of salinity : *A. typus* is an euryhaline species which can tolerate wide ranges of salinity. Even though they are usually found in the fresh water regions, their survival is only marginally affected in higher saline media. Thus it was found that the adults behaved normally in salinities 1.72 ‰ to 16.7‰, but ceased their activities, sank to the bottom and lay motionless in higher salinities. But when they were transferred back to normal pond water, they regained their normal activities after a period depending on the strength of the previous solution and the duration of the immersion in it. However, the oxygen consumption of the adult and gravid females of *A. typus* showed a pronounced decline from low to high salinities. Thus there was a significant decline in oxygen uptake at 100% sea-water (33.4‰) as compared to 5% and 10% S.W. for both adult and gravid females (Table 1).

The effect of salinity on the development of eggs and embryos in the brood pouches showed that development was severely affected in higher saline media (Table 2). Thus in salinities higher than 16.7‰, a tendency to discard the eggs and embryos from the marsupia was noticed. Deterioration of eggs and embryos and total mortality of young ones were also observed in higher saline media.

Effect of temperature : A. typus (body length ranging from 12 mm to 15 mm) kept in 400 cc of pond water were immersed in a water bath and were subjected to a slow rise in temperature at the rate of approximately 1°C per hour by means of a thermostat. These animals behaved normally upto 38°C, but their movements became more rapid with increasing temperatures until death coma set in at 39.5°C and they became motionless and sank to the bottom of the dish. Death occurred when the temperature reached 41.5°C to 41.8°C. Since these animals were found to tolerate higher salinities without much difficulty, an experiment was also set up to investigate the relation between salinity of the water and temperature tolerance. From the studies it appeared that the lethal temperature varied over a range of 2.5°C depending on the salinity of the media. As the salinity of the medium increased, the lethal temperature came down (Table 1).

Breeding biology

The breeding activities of *A. typus* and the recruitment into the population are almost continuous throughout the year. The sexes are separate and the reproductive organs are enclosed within the thorax. The secondary sexual characters begin to develop when the animals attain a body length of 9 to 10 mm. At this stage, females can be distinguished

TABLE 1. *Oxygen consumption and lethal temperatures of adults of* A. typus *in different salinities tested*

Salinity (%)	Oxygen consumption (ml/g/lit/h/animal) Adult	Gravid female	Lethal temperature (°C) Mean temp. at which death coma starts	Mean temp. at which death occurs
5% S.W. ..	0.62	0.35	41.50	41.80
10% S.W. ..	0.56	0.35	41.50	41.75
20% S.W. ..	0.53	0.34	41.50	41.75
30% S.W. ..	0.50	0.33	41.20	41.50
40% S.W. ..	0.50	0.33	40.90	41.20
50% S.W. ..	0.49	0.33	40.70	40.80
60% S.W. ..	0.46	0.27	40.30	40.70
70% S.W. ..	0.39	0.18	39.50	40.20
80% S.W. ..	0.29	0.09	39.50	40.05
90% S.W. ..	0.21	0.06	39.40	39.80
100% S.W. (33.4‰) ..	0.12	0.03	39.00	39.50

TABLE 2. *Development of eggs, embryos and larvae inside the marsupia of gravid females in varying salinities*

Salinity (‰)	Stage exposed	Observations
1.72 (5% S.W.) 3.34 (10% S.W.)	Eggs, embryos and larval stages	Development normal and in synchrony
	Eggs and Embryos	Development almost normal. Slight delay in shedding the egg and embryonic membranes was noticed.
8.35 (25% S.W.)	Larval stages	Development normal. Movement inside the marsupia slightly rapid
	Eggs and Embryos	After an exposure period of about 4 days, tendency for deterioration starts. Gravid females also start ejecting the eggs and embryos slowly from the marsupia. Hatching completly blocked.
16.7 (50% S.W.)	Larval stages	Tendency to come out of the marsupia of the gravid females is shown. All dead after 7 to 10 days of exposure
	Eggs and Embryos	Hatching completly blocked. Deterioration of eggs and embryos starts after exposing them for 3 days in the medium. A tremendous tendency to eject the eggs and embryos from the brood pouch is shown by the gravid females.
25.05 (75% S.W.)	Larval stages	Unable to survive in the medium. All dead within 1 to 2 days of exposu re in the medium.
	Eggs and Embryos	Complete deterioration starts after 24 hours of exposure in the medium. Gravid females start shedding all the eggs and embryos from the brood pouch within 24 hours of exposure in the medium.
33.4 (100% S.W.)	Larval stages	Totally unable to survive in the medium. All dead within 24 hours of exposure in the medium.

by the presence of oostegites which are rudimentary attached to the base of the 3rd to 6th peraeonic segments, and males by a pair of papillae on the ventral side of the seventh thoracic segment and by the appendix masculina on the endopods of the second pleopods. Apart from these, the seventh paraeopod in adults are slightly longer in males compared with those of females and the sixth thoracic segment becomes the broadest in adult males while in females the broadest region moves forwards at maturity to the third thoracic segment.

Ovigerous females were present throughout the period of study with a peak during the initial months of the year. Males were generally fewer in number in the population. Studies on the sex-ratio indicated a preponderance of females almost throughout the year except in April, when an even sex-ratio was noted (Table 3). The number of newly deposited eggs produced by gravid females of *A. typus* was related to the body length of the incubating female and the monthly variations in the brood composition showed a sequential pattern in which a peak of females bearing eggs was followed by a peak of females bearing embryos and later a preponderance of juveniles in the population. Brood mortality in any stage of development *viz.* the eggs or the embryos was not noticed. The incubation period from fertilized egg in the brood pouch to the release of the larvae ranged from 42 to 53 days. Of the 16 gravid females whose body length ranged from 11 mm to 16 mm and whose total incubation period was definitely determined, the average was 42 days. Young ones (>3.5 mm and <5.0 mm body length) were collected throughout the year and their maximum incidence was noted during the initial months of the year and also towards the end of the year of study (January-December, 1977).

TABLE 3. A. typus : *Sex ratio during* 1977

Month	Ratio Male		Female
January ..	1	:	1.23
February ..	1	:	1.25
March ..	1	:	1.35
April ..	1	:	1.00
May ..	1	:	7.30
June ..	1	:	2.63
July ..	1	:	1.57
August ..	1	:	4.00
September ..	1	:	1.84
October ..	1	:	6.00
November ..	1	:	1.14
December ..	1	:	2.00

It was noted that the newly released juveniles require fishes or tadpoles as hosts since they lead a parasitic life during the initial period of their life cycles. The growth of these juveniles is severely curtailed once they are deprived of these hosts. With a view to studying this, observations were made on 100 juveniles (3.5 to 5.0 mm) some with hosts and others without them. These tests which lasted for more than a month revealed that the body length of juveniles provided with hosts has almost doubled during the period when compared with those without hosts.

The Biochemical and haematological changes in the host fishes due to the infestation of A. typus

Juveniles of *A. typus* (3.5 to 8.0 mm) attached to the gill chambers of fishes were found to feed on the blood and mucus. When removed from the hosts and examined, their gut was seen distended by the ingested blood. The position of the parasite inside the gill chamber is also characteristic being attached to the upper part of the gill arcs facing the water flow or in the buccal cavity itself clinging to the floor facing the water flow. In the majority of cases, they are typically found in one gill chamber only. Oxygen uptake in the parasitized gill chamber would naturally be reduced and possibly this accounts for infestation in only one gill chamber so that the damage to the host is reduced. Occasionally a single fish with several juveniles on both gill chambers has also been noticed with opercula widely opened and gills severely demaged. But such cases were rare.

Experimental observations made on the host-specificity shown by these parasites revealed that they do not show any host preference at all and that they attach indiscriminately to any fish that comes its way, the only factors that determine the attack being probably the speed of the fish and the area it inhabits.

The biochemical and haematological changes in the host fish as a result of infestation were studied in *Tilapia mossambica* and *Channa striatus* respectively. To study the biochemical changes, 5 juveniles (3.5 to 7.0 mm) were allowed to attack the host fish *T. mossambica* for 8 hours. A total of 10 adult males and females each of the non-infested and infested fishes were taken for the study and after the infestation period, 2 each of the infested males and females were kept separately for 20 hours to study the rate of recouperation of the lost organic constituents. The results are presented in Table 4. The haematological changes in the host fish *C. striatus* were checked after subjecting them to the attack of 15 juveniles (5.0 to 8.0 mm) and after 24, 72 and 120 hours of the introduction of these parasites, 2 each of the host fish were taken and their haematological parameters were studied. Control specimens were also kept. The results of the study are presented in Table 5.

The results of the biochemical analyses revealed that the host fish is affected by isopod infection. There was an increase in the moisture content and a sizeable depletion in the glycogen, protein and lipid in the infested fishes of both sexes as compared with the non-infested ones. But a remarkable ability to regain the lost constituents during the recouperation period was noticed in these fishes (Table 4).

The haematological parameters of the infested *C. striatus* as compared with the non-infested ones show a change in the blood picture of the former as a result of attack (Table 5). Thus the feeding of the host blood by the parasite caused a reduction in the total erythrocyte count, haemoglobin content and

TABLE 4. *Changes in the biochemical constituents of the host fish* Tilapia mossambica *due to the infestation of juvenile* A. typus

Duration of Infestation : 8 hours
Total number of juveniles provided to each fish : 5
Duration of Recouperation : 20 Hours

Condition of the fish	Sex	Total No. taken	Mean body length (mm)	Water content (%)	Glycogen (%)	Lipid (%)	Protein (%)
Non-infested ..	Male	10	49.00	72.79	5.18	9.85	64.81
	Female	10	45.75	74.24	6.38	10.20	59.00
Infested ..	Male	8	47.25	75.11	0.68	2.56	53.37
	Female	8	46.25	75.43	0.93	6.44	51.80
Recouped ..	Male	2	50.00	72.24	1.23	7.98	62.24
	Female	2	45.00	72.41	4.40	9.08	56.25

TABLE 5. *Haematology and the total and differential counts of WBC of the non-infested and infested fishes of* Channa striatus *due to the parasitization of* A. typus

Condition of the fish	Mean Red cell counts ($\times 10^6$ mm³)	Mean haemoglobin (g/100 ml)	Haematocrit or P.C.V. (%)	E.S.R. (mm/h)	M.C.V. µm³	M.C.H. µµg	M.C.H.C. (%)	V.I.	C.I.	S.I.	W.B.C. (Total count) (mm³)	Lymphocytes (%)	Plasmacytes (%)	Monocytes (%)	Neutrophils (%)	Macrophage (%)
Non-infested	4.58	16.8	45.0	1.00	98.25	36.88	37.33	1.00	1.00	1.00	57750	66.21	30.14	1.37	2.28	0.00
Infested for																
24 Hours	3.73	15.2	41.5	1.25	111.26	40.75	36.63	1.13	1.10	0.98	46530	87.92	10.00	0.65	0.39	1.04
72 Hours	3.58	14.0	40.2	1.50	112.29	39.11	34.82	1.14	1.06	0.93	29040	82.84	15.96	0.00	0.30	0.90
120 Hours	3.58	15.3	43.5	1.00	121.51	42.74	35.17	1.24	1.10	0.94	43560	78.79	19.19	0.51	0.51	1.00

haematocrit or packed cell volume of the fishes. Thus as the duration of the infestation increased, these values showed a decreasing trend which was maintained till 72 hours of infestation after which a slow rise in these values was evident and a tendency towards reaching normalcy was noted after 120 hours. The results of the analyses of erythrocyte constants also showed an increase in the mean corpuscular volume, mean corpuscular haemoglobin, volume and colour indices and a decrease in the mean corpuscular haemoglobin concentration and saturation index as the infestation progressed.

The results of the study of the total and differential counts of WBC in the peripheral blood of *C. striatus* indicate a decrease in the total count of WBC coupled with an increase in the percentages of lymphocytes and macrophages and a decreasing trend in the percentages of plasmacytes, monocytes and neutrophils.

TABLE 6. *Juvenile A. typus : Estimated LD_{50} values and confidence limits (P=0.05) for five technical grade organophosphate biocides in bioassays conducted at 27±3°C*

Biocide	LD_{50} Log value	LD_{50} converted to dose	LD_{50} on ppm/48 hours with fiducial limits
Folithion	0.7957±0.1715	0.575	0.00095 (0.00065—0.00142)
Nuvan	0.5683±0.0574	0.370	0.00925 (0.00811—0.01056)
Malathion	0.3263±0.0708	2.100	0.05250 (0.04503—0.06238)
Hinosan	0.4460±0.0817	2.793	0.27930 (0.2313—0.3371)
Dimecron	0.3152±0.0390	2.067	5.16750 (4.70—5.65)

Effect of certain biocides on A. Typus *(Juveniles)*

Eradication of *A. typus* (Juveniles) from a nursery or pond is highly desirable for achieving success in pond cultures. Thus the possibility of chemical control of these parasites has been attempted and found to be successful. The biocides used for the present study are all members of organophosphate groups which are widely used in the rice fields and fresh water bodies of the region. These biocides are (1) Folithion 50 EC (2) Nuvan 100 EC (3) Malathion 50 EC (4) Dimecron 100 EC and (5) Hinosan 100 EC. Juveniles of *A. typus* (3.5 to 7.0 mm) were used. Table 6 shows the comparative statements of LD_{50} values with their confidence limits (P=0.05) in ppm for 48 hours for the biocides used. As may be seen from the Table, LD_{50} values for the different biocides showed wide differences. Thus among the various biocides used, Folithion and Nuvan were found to be very toxic, where a concentration of 0.00095 ppm and 0.00925 ppm respectively were enough to bring 50% mortality of these animals in 48 hours. LD_{50} values for Malathion and Hinosan were 0.0525 ppm and 0.2793 ppm respectively. Dimecron was found to be least toxic and its LD_{50}/48 hours value was found to be 5.167 ppm.

DISCUSSION

Alitropus typus is an euryhaline species which can withstand considerable variations in salinity and temperature of the medium in which it inhabits even though the normal embryonic development occurs only in a fresh or slightly brackish water media. Experiments on salinity tolerance showed that *A. typus* can withstand even high salinity for long periods by reducing their activity and this is of survival value.

Salinity changes are sometimes associated with changes in temperature and as temperature moves up, evaporation causes salinity to rise. The experiments showed that with increasing salinity, temperature tolerance of *A. typus* comes down. Observations in the fresh water lakes and brackish water region over a period of two years (January, 1977 to December, 1978) have shown that the fluctuations in salinity and temperature in the sites ranges from 0.5 to 4.5‰ and 25.3 to 32.2°C respectively. These changes are well within the tolerance limits of these animals. Brusca (1966) stated that physiologically the tolerance of different isopod species to variations in humidity and salinity correlate with the particular habitat involved and illustrates adaptations to the situations in which each species is found.

Observations on the adult and gravid females of *A. typus* revealed a marked rise in oxygen uptake in low salinities. This is a well known phenomenon but the cause of it has not been adequately explained. Frier (1967) has recorded an increase in oxygen uptake by the isopods *Sphaeroma rugieauda* and *Sphaeroma hookeri* when going from high to low salinities. It has been argued that the rise is solely due to the rise in respiration of the epithelial cells caused by the increasing active transport work done to regulate osmotic pressure. Potts and Parry (1963) on the other hand believe that apart from the above mentioned factor other factors contribute significantly in the rise in respiratory rates at lower salinities.

The most salinity sensitive stages in the life cycle of *A. typus* occur in the marsupium. This is in close proximity with the observations made on the brackish water isopod, *Cyathura polita* (Simpson) by Kelley and Burbanck (1976). In the present study total inhibition of development was observed in higher saline media (>16.7‰). The range of salinity in which normal development can proceed appears to be between 0.5 to 9‰ (end points excluded This is a narrower range that can be tolerated by the developing embryos of *A. typus*.

The breeding activities and recruitment into the population by *A. typus* take place throughout the year. The brood pouch is external in *A. typus* which is contrary to the observations made in most of the sphaeromids (John, 1968 Venkatakrishnan and Nair, 1973) where it is internal. The number of eggs produced by the gravid females of *A. typus* vary with the size of the female, which is a common phenomenon in isopods in general (Jones and Naylor, 1971, Ellis, 1971). Brood mortality is not observed in the present study and all embryos in a marsupium appear to be at the same stage of development. But the presence of mixed broods is reported in the wood-boring sphaeromids (Venkatakrishnan and Nair, 1973).

It has been suggested that incubating females of certain isopods do not feed but present observation shows that ovigerous females of *A. typus* accept food but they feed only for a short period, perhaps because the developing embryos within the brood pouch exert pressure upon the dilative anterior hind gut reducing its capacity for expansion.

The sex-ratio of males to females in *A. typus* show a preponderance of females in most of the months studied supporting the earlier works of Jones and Naylor (1971) and Venkatakrishnan and Nair (1973) on different estuarine and marine isopods. The occurrence of an excess of females almost throughout the year suggests that males are perhaps more vulnerable than females.

Parasitic isopods are formerly considered as being absolutely host-specific so that each species of host was assumed to harbor a distinctive species of parasite. However, further investigations made on this aspect revealed the fact that the host-parasite relationship is not as highly specialised as was formerly assumed and the relationship is found to be distinctly ecological and the infestation of these parasites occurs on appropriate hosts that appear in the cyclic fashion within a given biotope (Baer, 1952). observations on the host specificity shown by *A. typus* also agrees with the finding of Baer.

The results of the biochemical analysis on the host fish *Tilapia mossambica* reveal that the muscle tissue of the infested fishes show some changes with respect to its biochemical composition. The depletion of glycogen in the infested fishes is due to the feeding of blood by these parasites which utilize the blood sugar as a source of energy reserve. Glycogen may be utilized by arthropod parasite for the synthesis of chitin and also for moulting purposes (Renaud, 1949). It is quite possible that the parasite utilizes the lipid content for the development of musculature. On the other hand, the percentage reduction of protein in the infested fishes is not as high when compared with glycogen and lipid. It is generally recognized that parasites living in oxygen rich surroundings such as blood can theoretically derive most of their energy from the oxidation of lipids and proteins. In the present study, however, the percentage reduction of lipids in the host fish is substantially higher than that of protein and this indicates that the energy requirement of the parasite is met to a greater extent from lipids.

A blood feeding parasite can be expected to exert a significant influence on the composition of the blood of the host fishes. This influence is usually expressed as measureable changes in the peripheral blood. During the present study it was observed that the feeding of blood by the parasitic stage of the isopod has brought about noticeable haematological changes in the host fish, *Channa striatus*. The decrease in RBC count, haemoglobin and haematocrit caused by the infection, points to the fact that the infected fish becomes anaemic. Kabata (1970) had pointed out that the reduction in the haemoglobin content and drop in the erythrocyte count of the host fishes are characteristic features of the secondary anaemia induced by blood feeding parasites. The results of the present study on the changes in the RBC constants and indices of the host fish *C. striatus* infested with *A. typus* clearly indicate that the anaemia caused by the infection is of the macrocytic type as is evident from the increase in V.I. Considering M.C.H., M.C.V. & M.C.H.C., the anaemia may be designated as 'Severe-Macrocytic' as per the morphologic classification of anaemias according to Todd-Sanford's (1963) Scheme.

The results of the study of the total and differential counts of WBC in the peripheral blood of infected *C. Striatus* indicate leucopenia coupled with lymphocytosis. Leucopenia is usually due to a drop in the number of granulocytes because they are numerically the most frequent white blood cells (Todd-Sanford, 1963).

The results of the bioassay studies indicate that very low concentrations of different organophosphate biocides used are sufficient to bring 50% mortality among the juveniles of *A. typus* in 48 hour period. The five biocides tried have different degrees of toxicities. Among the five, Dimecron is the least toxic Hinosan more toxic, Malathion still more toxic and Nuvan and Folithion the most toxic. It is interesting to note that the lethal doses of different biocides for the juvenile *A. typus* are quite harmless to the various fishes tried.

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MONITORING OF HAEMATOLOGICAL PARAMETERS FOR HEALTHY MAINTENANCE OF CULTIVABLE SPECIES

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ABSTRACT

Earlier reports on haematological aberrations associated with disease manifestations are reviewed. Strategic importance of the study of various haematological parameters like composition of blood cells, haemoglobin content, mean corpuscular haemoglobin and packed cell volume is indicated. Regular monitoring of these parameters from time to time on fish stocks under intensive culture is emphasised. Significance of the deviation of these parameters from the normal values as aids in clinical diagnosis of the condition of the fish is pointed out. Usefulness of immunological adaptations as indicated by the blood group studies for selective breeding of cultivable species is suggested.

INTRODUCTION

HAEMATOLOGY of fishes has gained recognition as an applied science. Composition of blood of fishes varies with the changing conditions of the environment and responds immediately to any change in water quality because of the intimate contact. The parameters that can be easily measured are hematocrit (Hct), haemoglobin (Hb), counts of RBC and WBC and differential counts of the different cellular elements. From the beginning of this century great attention has been paid to the morphological description of the different types of blood cells. The comprehensive review of Ellis (1977) gives a standard nomenclature on the basis of functional, morphological and ontogenic criteria. The techniques borrowed from mammalian haematology are suitably modified to the study of fish haematology. Their appropriateness is evaluated in the several reviews made by Hesser (1960); Blaxhall (1972) and Ellis (1977). Now, there is a growing awareness of the application of haematology in the management of fish ponds used for culturing.

An attempt is made here to highlight the practical use of haematology to assess the condition of fish in closed-system cultures. Information available in literatures about the susceptibility of cultivable fish for disease and haematological response of the fish to changing conditions of water quality and disease, is collated. The possibility of advance assessment of deteriorating conditions of water quality, nutritional deficiency and parasitic infection which are likely to cause damage to culture fisheries, is shown.

HAEMATOLOGY IN RELATION TO WATER QUALITY

An acute epizootic infection causes irrepairable to the economic viability of a fish farm. The least expensive approach is to avoid stress on the fish stock by ensuring high water qulity with a close watch on the condition of the crop. Testing the water quality with regard to each of the parameters is not always possible. Some of the grossly measurable deteriorating qualities like depletion of oxygen, increase in toxic dissolved gases such as ammonia and hydrogen sulphide, liberation of free carbon dioxide, etc., which impose a heavy strain on the respiratory efficiency of fishes may be easily measured. But, the presence of sublethal levels of organic and inorganic substances like toxic metabolites and heavy metals which act as physiological depresents and render the fish easy target for parasitic infections cannot be easily detected. So, a kind of screening test which accounts for internal changes in the physiology of the fish in response to sublethal concentrations of toxic substances has to be adopted to ensure good quality of the water.

Sano (1960) was the first to recognise the practical use of haematology of fishes and proposed routine blood analysis for clinical purpose so that adequate measures against deteriorating water quality or latent infection can be taken before mortality of fish becomes serious. Later authors like Bouck and Ball (1966), Summerfelt (1967) McCarthy *et al.* (1973) and Blaxhall and Daisley (1973) and Hickey (1976) were quite optimistic about the role of haematology in practical management of fish farms.

Reichenblach-klinke and Elkan (1965) stated that the usefulness of blood studies in fishery management is limited because of the lack of species normal values. Blaxhall (1973) however, hoped to accumulate a ' bank ' of useful information if workes in the field employed the screening tests suggested by him so that valuable and informative conclusions can be drawn. Investigations carried out so far, mostly during the last decade has brought out considerable information. The progress in this direction is reviewed below.

Haematology in Relation to Environment

Temperature is an important factor which varies naturally with seasons. Gardner and Yevich (1969) found seasonal variation in the morphology of the blood cells and other studies by -Murachi (1959), Houston and De Wilde (1968) and Farghaly *et al.* (1973) showed that Hb, Hct, and R.B.C. increase with increasing temperature.

The influence of salinity is mainly a reduction of corpuscular volume. Farghaly *et al* (1973) however, observed increase in Hct, Hb and R.B.C. There was considerable increase in neutro-, eosino-and basophils at 19.75‰ and a drop in lymphocytes at 39.5‰. The total leucocytes as well as agranulocytes decreased at higher salinities.

Randall (1970) and Doudoroff and Shumway (1970) reviewed the effect of low dissolved oxygen which tend to increase the Hct, which is attributed to an increase in the volume of R.B.C. (Lloyd and Swift, 1976). The blood cells try to compensate by increasing the concentration of Hb and also increase in volume up to a certain limit beyond which there is a breakdown in the compensatory mechanism leading to fatalities (Summerfelt *et al.*, 1967 ; Sneizsko, 1974). The frequent increased mortalities in cultured carp in temperate waters occurring in spring is perhaps due to the failure of the compensatory mechanism after a severe winter (Sneiszko, 1974). Enomoto (1969) found decrease in leucocyte numbers also under oxygen deficient conditions.

The chemistry of the water in a closed system culture changes with the accumulation of Nitrogenous wastes excreted by the fish, and mineralisation of organic substances by heterotrophic bacteria, giving rise to toxic levels of ammonia concentration. This endogenous change has a profound effect on the physiology of the fishes. If there are concurrent fluctuations of temperature, changes in the levels of dissolved oxygen and free CO_2, due to phytoplankton abundance, there may be mass mortalities of fish. Such mass mortalities of *Megalops cyprinoides*, *Mugil cephalus* and *Nematolosa* sp. were observed by Ganapati and Raman (1976) in the Visakhapatnam Harbour which is highly polluted by industrial effluents containing heavy metals and acids. They reported abnormal quantities of free CO_2 released by the action of acids on the carbonates and bicarbonates in the water. The fish culturist should always anticipate the ammonia problem at maximum carrying capacity and maintain stable pH between 7.5 and 8 to minimize the toxic effects (Spotte, 1970).

Haematology in Relation to Pollution

The effect of heavy metals like Cu, Zn, Pb and Hg on the blood characteristics is very profound even at low concentrations (Spotte, 1970). Heavy metals precipitate and coagulate mucous on gill filaments, inhibiting oxygen uptake which is aggravated under hypoxic conditions killing the fish. Larsson *et al.* (1976) reported reduction in Hct, Hb, volume of RBC and the general effect was one of anaemia in fish exposed to cadimum even at as low concentrations as 0.1 mg/l. Gardner and Yevich (1970) reported disturbances in the leucocytes also at very high concentrations (50 mg/L). Srivastava and Misra (1979) also confirmed the same observation with regard to lead. In addition they observed increase in the number of erythrocytes in circulation. There was haemolytic anaemia also. Lone and Javaid (1976) also observed anaemia in the form of low RBC and Hb but with high MCH under the influence of DDT and Dieldrin. There was slight increase in lymphocyte and concommitant decrease in the monocytes.

Reichenblach-Klinke (1967) found that histological examination of fish exposed to sublethal levels of ammonia revealed congestion of mucous cells in the skin and an abnormal concentration of blood corpuscles in the epidermis. Blood vessels in the liver were congested and the liver itself was inflamed. The blood components were altered and erythrocytes were destroyed.

Haematology in Relation to Nutrition

Starvation as a stress factor reduces Hct, Hb and RBC. Joshi (1979) found the eruthrocytes shrunken and distorted after prolonged starvation. Halver (1969) studied the anaemic condition due to folic acid deficiency. Anisocytosis, nuclear segmentation of erythrocytic enucleate erythrocytes, retardation of the production of erythrocytic precursors and continued existence of mature and senile erythrocytes were the features of the blood stream in an anaemic fish. Megaloblastic macrocytic anaemia was experimentally produced by Smith and Halver (1969) in coho salmon fed on folic acid deficient diet.

Haematology in Relation to Disease

Anaemia in natural waters was reported by Kawatsu (1969) in the brook trout and Usha Rani and Srinivasa Rao (1979) in a euryhaline fish *Elops saurus*, from Visakhapatnam harbour. The former reported reduced RBC, MCV, MCD and an increase in Hb without any change in MCHC and concluded that the diseased fish developed macrocytic anaemia without any external symptoms. Anisocytosis, fragmentation of nuclei and enucleate erythrocytes were also observed. Hypersegmentation of the neutrophils was also observed. Usha Rani and Srinivasa Rao (1979) also reported low RBC, high WBC, the counts of which exceeded the three standard deviations limit of the normal mean values. Neutrophiloblasts, small haemoblasts along with increase of neutrophils, slight increase in erythroblasts and decrease of thrombocytes were additional features of the anaemic fish.

The reasons for some other gross changes like cytoplasmic inclusions in erythrocytes in the moribund pacific herring off British Columbia collected during an incidence of mass mortality (Tester, 1942) were not identifiable till it was shown by Laird and Bullock (1969), Sherburne (1973), Johnston and Davis (1973) and Bull and Margolis (1976) that erythrocytes in fishes infected with virus are characterised by the inclusion of such bodies.

Lagler *et al.* (1961) in the case of *Pseudomonas* infection of carps and Smith (1968) in the case of *Vibrioses* infection in chinook salmon reported reduced RBC, WBC, Hb. Reduced Hct was also reported by the latter. Lagler *et al.* (1961) further stated that monocytes increased from 5.7 to 38.0‰ and polymorphonuclear leucocytes increased from 2.3 to 12.6%. On the other hand Karpenko and Vaslyushko (1961) reported a decrease in RBC and doubling in leucocyte numbers in carp (*Cyprinus carpio*) with infectious dropsy. Smirnova (1964) however, reported that the internal parasites of the bream caused a rise in RBC and Hb and a reduction in leucocytes. Malcahy (1971) reported higher Hct values in trout infected with ulcerative dermal necrosis (UDN). Hines and Spira (1973) reported drop in lymphocytes and progressive increase in neutrophils with infection of ichthyophthiriasis in minor carp and showed evidence to suggest that the response of carp to any stress syndrome not directly involving the haemopoietic system, is lymphopenia and neutrophilia proportionate to the degree of stress. These observations are at variance and it is not possible to determine at this stage whether the effect of infection on cellular composition is characteristic of each type of infection or species specific.

Casillas and Lynwood (1977) recommended the employment of clotting time as an indicator of stress. The parameter is apparently a function of number of thrombocytes present. It is easier to measure the clotting time rather than the number of thrombocytes which are capable of changing shape and difficult to distinguish from 'distorted' small lymphocytes (Ellis, 1977).

Discussion

A perusal of the literature shows that substantial progress has been made in detecting anaemic condition of fish. Anaemia might arise from nutritional deffciency (Smith and Halver, 1969) or stress conditions (Usha Rani and Srinivasa Rao, 1979). Increase in the haematological parameters due to oxygen deficiency and raise in temperature is understandable as a physiological adjustment. The effect of salinity, toxic substances and disease which implicates a change not only in the RBC but also in the leucocyte composition is not yet clear. Non-familiarity with leucocyte morphology was perhaps the stumbling block in the past. Now, there is considerable information and it is hoped that current and future work will make the relationship between leucocyte response and environmental factors very clear so that specific diagnosis of a disorder in the physiology of the fish becomes possible.

Hines and Spira (1973) discussed about the Russian school of thought which gives importance to the leucocytic formula in the differential diagnosis of fish diseases. So, it indicates that the RBC and WBC numbers respond more to environmental changes and leucocytes, particulraly neutrophils respond to infectious diseases. Ellis (1977) also stated that neutrophils are versatile in their function being phagocytic, responding to inflammation, chemotactic stimulus and effects of stress.

Hines and Spira (1974) showed that carp recovered from heavy ichthyophthiriasis caused by *Ichthyophthirius multifilus*, possess varying degrees of resistance to subsequent reinfection.

Immunity is so variable that a culture of *J. multitilus* obtained from cat fish is virulent only towards cat fish, whereas a strain obtained from gold fish is usually lethal to most other fish. Klontz (1972) suggested some sets of conditions and gave descriptions of leucocytes to standardise the knowledge about the haematological sequence of events following the administration of an antigen.

Conclusions

There is a widespread approval of the use of haematology as a tool in the hands of fishery biologists and research ichthyologists for the efficient management of fish farms. The limitation at present is inadequacy of normal values. McCarthy *et al.* (1973) suggestion that deviations up to ±2 standard deivations from the normal mean values might be considered compatible with health, can be used as a yard stick to assess the health of the fish. Future work on haematology should be carried out in a routine manner to document long term trends with reference to levels of exposure to different environmental conditions for direct observation of acute effects. Due consideration must be given to statistical treatment of the data to make the information more valuable from the point of view of drawing valid conclusions. Immune response studies would in future strengthen the hands of the fish farmer to build up a strong race of fish which can withstand stress conditions very effectively without the intervention of human help. Until then, good husbandry of the fish farm is necessary with haematology playing a very important role.

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ROLE OF TIDAL INFLUENCE ON THE DEGREE OF INDUSTRIAL POLLUTION CAUSED BY SULPHITE PULP AND PAPER MILL WASTE IN THE HOOGHLY ESTUARY NEAR HAZINAGAR

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ABSTRACT

The Hooghly estuarine system in the east coast of India is extremely important from the fisheries point of view due to its high potentialities for seeds of cultivable brackishwater fish and prawn. It is distinctly vulnerable to pollution hazards caused by the discharge of various trade effluents (0.405 mill m^3/d). The paper deals with the role played by three different tidal phases namely neap (NT), spring (ST) and bore tide (BT), prevalent in this particular system, on the degree of environmental damage caused to the estuarine ecosystem under low and high tide (LT & HT) due to man-made activities like disposal of putrescible organic and oxidisable inorganic matter from a sulphite pulp and paper mill situated about 58 km upstream of Calcutta. The study related to the year 1973-'74.

The investigations revealed that during all the tidal phases, the BOD and OC values were mostly greater during LT compared to HT condition. The annual average value of BOD, OC and alkalinity during LT indicated the same trend, while DO indicated lower value in LT in the entire stretch of 1.25 km below the outfall which reveals that the pollution load is more pronounced during LT than HT condition. This finding is also supported from the results of higher %reduction in DO value during LT. The inverse relationship of DO with BOD and OC was indicated from higher% gain in BOD and OC values.

An appreciable deterioration in water quality with respect to DO, BOD, OC and alkalinity has been indicated during LT under NT condition as compared to ST and BT.

The average current velocity indicated the order of 48.4 cm/sec in NT, 53.1 cm/sec in ST and 57.1 cm/sec in BT which reveals that the impact of pollutants is likely to be more pronounced during NT situation due to more sluggishness of the tidal current. The extent of lateral dispersion of the coloured pollutants from the sulphite mill being in the order of 37.1 m, 19.8 m and 19.1 m during NT, ST and BT respectively lends further support to this view. The biological condition with respect to plankton abundance was adversely affected during NT as compared to ST and BT condition. Suggestions for the control of pollution have been made.

INTRODUCTION

POLLUTION of estuarine waters of the country by various waste waters has increased so rapidly (Gopalakrishnan *et al.*, 1970); Basu *et al.*, 1970; FAO 1967) that coastal aquaculture operations may be threatened unless adequate steps for abatement of pollution are taken.

The Hooghly estuary, sustaining several commercially important fisheries, has become a dumping ground of pollutants from a large number of industries between Dumurdaha and Haldia, a stretch of about 166 km (Fig. 1). 0.405 mill m^3/d of effluents are discharged by these industries into the estuary with inadequate treatment creating an environment, which is detrimental to fisheries. The estuary is reported to have deteriorated in its biogenic capacity in some stretches receiving major pollutants from industries, such as pulp & paper, rayon, rubber, distillery and yeast which are responsible for alterations in the physico-chemical and biological conditions of the environment (Gopalakrishnan *et al.*, 1973; Bagchi, 1976; Ghosh *et al.*, 1976, 1977, 1978; Ray *et al.*, 1977, 1978; Ghosh and Bagchi, 1978, 1979).

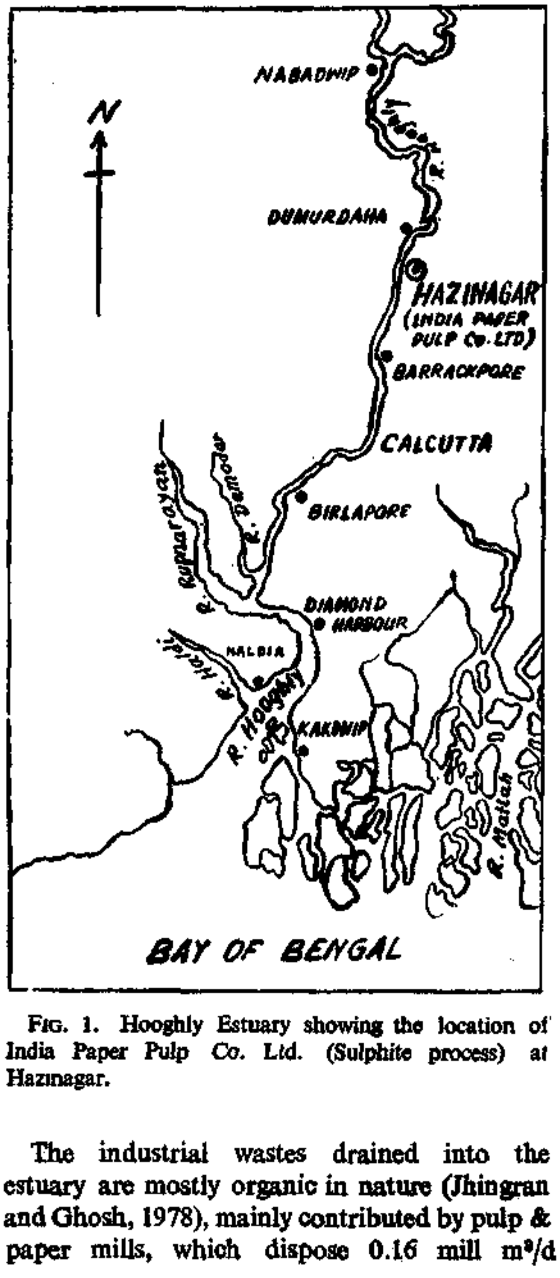

FIG. 1. Hooghly Estuary showing the location of India Paper Pulp Co. Ltd. (Sulphite process) at Hazinagar.

The industrial wastes drained into the estuary are mostly organic in nature (Jhingran and Ghosh, 1978), mainly contributed by pulp & paper mills, which dispose 0.16 mill m^3/d accounting for more than half of the total disposed industrial waste waters (Ghosh *et al.*, 1973). The pollution problems arising from the effect of effluents of a sulphite process pulp & paper mill on the estuarine environment during various phases of low and high tides have been dealt in this communication. The selected paper mill is situated 58 km upstream of Calcutta, near Hazinagar. The study relates to the period 1973-'74.

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MATERIAL AND METHODS

Effluents drained from pulp, paper machine and bleaching process units were collected monthly by grab sampling method and analysed for various physico-chemical parameters following standard methods (APHA, 1971). Five sampling stations along a 1800 m marginal stretch of the estuary within 5-6 m from the water edge were selected, one upstream, three downstream and one at the effluent discharge point. Surface water samples were collected during lowest (LT) and highest (HT) water levels of neap (NT), spring (ST) and bore (BT) tidal phases of three distinct seasons *viz.* summer (March-June), rainy (July-October) and winter (November-February). Simultaneously, plankters were sampled by straining 50 litres of water through a plankton net of bolting silk no. 25 XXX, preserved in 5% formalin and counted numerically under a microscope using a Sedgewick Rafter Counting Cell.

OBSERVATIONS

Characteristics of the waste waters

The effluents from both pulp and paper machine units were discharged at higher temperature (av : 32.8°C and 33.1°C respectively) than the ambient temperature (av : 29.5°C), while it was reverse in the bleaching unit. The wastes from both pulp and paper machine units were mostly acidic (average pH 6.6 and 6.3 respectively), while that of Ble ching unit was distinctly alkaline (average pH 10.1). Organic load (BOD and ½ hr OC) was considerably high in Pulp unit wastes. High specific conductivity and presence of available chlorine (16-1704 mg/l) were recorded in bleaching unit wastes (Table 1).

Average DO of pulp unit was low (about 1.0 mg/l) during all the seasons, while a comparatively high value (about 4.9 mg/l) was recorded in the paper machine units during summer and winter. High values of BOD, OC and alkalinity were registered in the pulp unit during winter, whereas the paper machine unit exhibited high BOD in summer (Table 2).

Hydrobiological condition in the estuary around the outfall

Tables 3-7 present the physico-chemical conditions at various sampling stations during low and high water levels under different tidal phases and seasons.

Station No. 1 (750 *m above outfall*)

During all the tidal phases of LT and HT, DO was highest in winter followed by rainy and summer seasons, whereas BOD was in the reverse order. The average alkalinity indicated a higher trend during LT and HT of NT. During LT and HT, the chloride values were 10-30 mg/l and 8-40 mg/l respectively. pH ranged between 8.0 and 8.4 during both LT and HT (Table 3).

Station No. 2 (*outfall*)

Average DO was lower during LT of all the tidal phases, particularly during summer and winter, as compared to that during HT. BOD indicated a higher trend during LT. Annual average OC indicated higher values during NT (LT). Highest alkalinity (av: 479 mg/l) was indicated during NT (LT) of summer and it was also reflected in the annual trend. Chloride ranged between 10-860 mg/l during LT and between 12-400 mg/l during HT. pH varied between 4.6 and >10.5 during LT and between 5.5 and >9.6 during HT, maximum fluctuations being observed during NT (LT) (Table 4).

Station No. 3 (250 *m below outfall*)

Low average DO was recorded during all the tidal phases of summer, particularly during NT (LT). Higher BOD and OC were indicated during the three tidal phases and seasons in LT, which was also reflected in the annual trend as compared to those above the outfall. OC values were high during NT of summer and winter, both during LT and HT. Average alkalinity indicated a higher trend, particularly during NT (LT) of all the seasons. Average chloride exhibited a similar trend like alkalinity. On an annual average basis, pH was on the increasing trend during NT (av : 8.9) as compared to ST and BT (both average 7.6) in LT (Table 5).

Station No. 4 (750 *m below outfall*)

Average DO indicated a decreasing trend during LT of all the tidal phases and seasons, whereas an increasing trend was noted in BOD. A similar trend in OC was noted as BOD and higher values were observed, particularly during NT of all the seasons, both during LT and HT. Chloride values were in the range of 6-44 mg/l during LT and 8-30 mg/l during HT. Higher alkalinity was indicated during NT(LT) of all the seasons and it was reflected in the annual trend. pH was in the range of 7.6-8.5

TABLE 1. *Characteristics of the combined effluent from major units of the sulphite pulp and paper industry located on the bank of the Hooghly Estuary during* 1973-'74

Parameters observed	Pulp unit Max	Pulp unit Min	Pulp unit Mean	Paper machine unit Max	Paper machine unit Min	Paper machine unit Mean	Bleaching operation unit Max	Bleaching operation unit Min	Bleaching operation unit Mean
Air temperature (°C) ..	36.2	21.0	29.5	36.2	21.0	29.4	34.0	28.5	31.8
Temperature of the effluent (°C) ..	40.0	27.0	32.8	40.5	26.0	33.1	33.0	27.8	31.2
Appearence ..	Brownish yellow			Whitish			Milky white		
Smell ..	Offensive			Faint smell			Chlorinous		
Turbidity (Silica scale) ..	>1000	<85	445 (approx)	>1000	<85	482 (approx)	>1000	140	570 (approx)
Specific conductivity at 25°C, × 10^{-6} mhos ..	1675	96	1155	1439	514	906	10284	7199	8741
pH ..	8.9	5.2	6.6	9.1	4.6	6.3	>10.5	9.0	10.1 (approx)
Total alkalinity as $CaCO_3$ (mg/l) ..	1000	44	300	380	7	92	1134	84	719
D.O. (mg/l) ..	4.5	0.0	0.7	6.7	0.0	3.7	0.0	0.0	0.0
$KMnO_4$ demand (mg/l)									
½ hr at 100°C ..	2360	47	822	1686	3	308	6	1	4
3 min at ambient temperature	978	11	173	384	0	58	0	0	0
4 hr at ambient temperature ..	1762	21	497	756	2	148	4	0	1
4 hr : 3 min. OC ..	13	0.5	4	16	0.4	3.7		..	
BOD_5 at 20°C ± 1°C (mg/l) ..	1920	400	986	876	60	265	133	84	—
Available chlorine (mg/l) ..	—	—	—	—	—	—	1704	16	409

TABLE 2. *Seasonal characteristics of the combined effluent discharged from the sulphite pulp & paper industry located on the bank of the Hooghly Estuary during* 1973-'74 *(Range with average values in parenthesis are indicated)*

Parameters observed	Pulp unit March—June	Pulp unit July—October	Pulp unit November—February	Paper machine unit March—June	Paper machine unit July—October	Paper machine unit November—February
Air temperature (°C) ..	36.2—28.0 (32.3)	35.0—27.2 (30.7)	32.1—21.0 (26.5)	36.2—28.0 (32.3)	35.0—27.2 (30.6)	32.1—21.0 (26.5)
Waste water temperature (°C)	36.2—30.0 (33.9)	40.0—31.5 (34.5)	39.0—27.0 (30.7)	37.0—30.2 (34.5)	40.5—33.0 (35.7)	35.5—26.0 (30.0)
Turbidity (silica scale)	>1000—<85 (346 app.)	>1000—102 (56 app.)	933—190 (436)	>1000—173 (462 app.)	870—125 (409)	800—<85 (545 app.)
Specific conductivity at 25°C, × 10^{-6} mhos ..	1675—799 (1254)	1319—96 (878)	1439—1107 (1271)	1439—659 (931)	1439—514 (980)	960—689 (821)
pH ..	6.0—8.1 (6.9)	5.2—8.9 (6.6)	5.8—7.2 (6.6)	4.6—8.2 (6.4)	5.0—9.1 (6.4)	5.0—6.9 (6.1)
Total alkalinity as $CaCO_3$ (mg/l)	700—126 (303)	280—105 (163)	1000—44 (397)	230—7 (97)	168—23 (74)	380—12 (99)
D.O. (mg/l) ..	3.4—0.0 (1.1)	4.5—0.0 (0.6)	2.9—0.0 (0.6)	6.7—3.2 (4.8)	5.0—0.0 (1.3)	6.2—3.2 (4.9)
$KMnO_4$ demand (mg/l)						
½ hr at 100°C ..	984—47 (400)	1918—140 (830)	2360—302 (1124)	140—3 (63)	1424—28 (564)	1686—31 (323)
3 min at ambient temperature	425—11 (130)	978—48 (226)	318—77 (165)	62—1 (15)	284—7 (121)	384—0 (49)
4 hr at ambient temperature	870—21 (295)	1762—100 (518)	1580—27 (630)	65—2 (34)	700—18 (320)	756—26 (111)
4 hr : 3 min OC ..	12—0.5 (3.4)	10—1 (3.9)	13—2.1 (4.6)	16—0.4 (4.3)	11—1.8 (4)	3.8—1 (2.9)
BOD_5 at 20°C ± 1°C (mg/l) ..	1315—400 (976)	722—400 (587)	1920—780 (13.6)	876—60 (454)	140—60 (88)	232—74 (153)

Table 3. *Seasonal and annual fluctuation on the hydrological conditions of the Hooghly Estuary in the vicinity of sulphite pulp & paper industry near sampling station No-1 (750 m above outfall) during* 1973-'74 (Range with average values in parenthesis are indicated)

	Tide	Low Tide: pH	Low Tide: DO (mg/l)	Low Tide: BOD_5 at 20°C+1°C (mg/l)	Low Tide: $KMnO_4$ demand (mg/l) ½ hr OC at 100°C	Low Tide: Alkalinity as $CaCO_3$ (mg/l)	Low Tide: Chloride as Cl (mg/l)	High Tide: pH	High Tide: DO (mg/l)	High Tide: BOD_5 at 20°C +1°C (mg/l)	High Tide: $KMnO_4$ demand (mg/l) ½ hr OC at 100;C	High Tide: Alkalinity as $CaCO_3$ (mg/l)	High Tide: Chloride as Cl (mg/l)
Summer (March-June)	NT	8.0-8.3 (8.2)	5.0-5.9 (5.3)	1.4-5.0 (4.1)	2-10 (6)	172-308 (204)	16-22 (19)	8.0-8.2 (8.1)	4.1-6.0 (5.1)	2.5-4.9 (4.1)	2.11 (8)	140-273 (203)	16-25 (20)
	ST	8.0-8.2 (8.1)	4.5-6.4 (5.3)	3.0-4.8 (4.0)	2-11 (6)	168-241 (193)	20-22 (21)	8.0-8.2 (8.1)	4.8-6.2 (5.4)	2.6-5.8 (3.9)	2-12 (7)	156-230 (190)	20-31 (25)
	BT	8.0-8.2 (8.1)	3.7-6.2 (5.7)	1.0-4.5 (3.5)	2-7 (5)	154-229 (188)	18-22 (20)	8.0-8.2 (8.1)	3.7-6.6 (5.6)	2.5-4.6 (3.4)	2-10 (8)	112-229 (184)	18-22 (20)
Rainy (July-October)	NT	8.0-8.1 (8.0)	5.1-6.1 (5.7)	1.0-5.5 (3.9)	2-7 (6)	125-287 (203)	12-24 (17)	8.0-8.2 (8.1)	3.8-6.6 (5.5)	2.0-4.6 (3.9)	3-20 (16)	154-300 (201)	8-40 (18)
	ST	8.0-8.2 (8.1)	4.6-6.6 (5.7)	1.8-5.7 (3.5)	2-7 (5)	128-321 (200)	12-20 (14)	8.0-8.2 (8.1)	4.6-6.0 (5.5)	1.6-5.2 (3.4)	2-8 (6)	120-307 (200)	11-20 (14)
	BT	8.0-8.2 (8.1)	4.6-6.7 (5.8)	2.2-5.2 (3.2)	1-8 (6)	130-283 (199)	12-14 (13)	8.0-8.1 (8.1)	5.2-6.8 (5.8)	1.6-4.8 (3.0)	2-10 (6)	120-288 (196)	8-13 (11)
Winter (November-February)	NT	8.0-8.2 (8.1)	4.6-7.5 (6.3)	0.9-5.7 (3.5)	2-8 (6)	78-185 (108)	10-20 (16)	8.0-8.4 (8.1)	4.1-7.8 (5.9)	1.6-7.1 (3.4)	7-23 (17)	77-170 (106)	20-20 (20)
	ST	8.0-8.2 (8.1)	5.4-7.9 (6.7)	0.6-5.0 (3.6)	1-14 (5)	84-147 (95)	13-20 (16)	8.0-8.1 (8.0)	2.4-7.7 (6.2)	0.6-7.6 (3.4)	5-20 (17)	78-139 (90)	14-23 (19)
	BT	8.0-8.2 (8.0)	4.6-8.6 (6.8)	0.6-3.6 (2.8)	0-7 (5)	67-117 (90)	19-30 (23)	8.0-8.1 (8.0)	3.4-8.7 (6.3)	0.6-6.4 (2.7)	4-13 (8)	49-123 (90)	17-30 (22)
Annual (January-December)	NT	8.0-8.3 (8.1)	4.6-7.5 (5.8)	0.9-5.7 (3.9)	2-10 (5)	78-308 (168)	10-24 (17)	8.0-8.4 (8.1)	3.8-7.8 (5.8)	1.6-7.1 (3.8)	2-23 (14)	77-300 (164)	8-40 (19)
	ST	8.0-8.2 (8.1)	4.5-7.9 (5.9)	0.6-5.7 (3.6)	1-14 (5)	84-321 (167)	12-22 (17)	8.0-8.2 (8.1)	2.4-7.7 (5.9)	0.6-7.6 (3.6)	2-20 (13)	78-307 (156)	11-31 (19)
	BT	8.0-8.2 (8.1)	3.7-8.6 (6.4)	0.6-5.2 (3.3)	0-8 (5)	67-283 (164)	12-30 (18)	8.0-8.2 (8.1)	3.4-8.7 (6.5)	0.6-6.4 (3.3)	2-13 (10)	49-288 (147)	8-30 (17)

NT — Neap tide ; ST — Spring tide ; BT — Bore tide.

TABLE 4. *Seasonal and annual fluctuation on the hydrological conditions of the Hooghly Estuary in the vicinity of sulphite pulp and paper industry near sampling station No-2 (Outfall) during* 1973-'74 (Range with average vaules in parenthesis are indicated)

		Low Tide						High Tide					
	Tide	pH	DO (mg/1)	BOD_5 at 20°C ± 1°C (mg/1)	$KMnO_4$ demand (mg/1) ½ hrOC at 100°C	Alkalinity as $CaCO_3$ (mg/1)	Chloride as Cl (mg/1)	pH	DO (mg/1)	BOD_5 at 20°C ± 1°C (mg/1)	$KMnO_4$ demand (mg/1) ½ hr OC at 100°C	Alkalinity as $CaCO_3$ (mg/1)	Chloride as Cl (mg/1)
Summer (March- June)	NT	6.1-8.1 (7.3)	0.0-2.2 (0.5)	43-2900 (1117)	12-2273 (675)	193-980 (479)	16-256 (83)	5.6-8.1 (7.3)	0.0-4.5 (1.3)	35-1820 (939)	5-1792 (633)	189-997 (337)	17-247 (78)
	ST	6.9-8.1 (7.5)	0.0-5.7 (0.8)	28-2800 (899)	5-1293 (659)	189-682 (461)	20-246 (134)	7.5-8.0 (7.7)	0.0-5.0 (1.9)	77-2100 (828)	8-1337 (616)	168-1320 (328)	21-300 (149)
	BT	7.5-7.8 (7.6)	0.0-4.7 (1.2)	120-1494 (780)	31-2243 (616)	60-1320 (364)	20-260 (174)	6.8-8.2 (7.8)	0.0-5.0 (2.3)	96-1344 (764)	2-2960 (604)	176-1210 (320)	18-230 (133)
Rainy (July-October)	NT	4.6-7.7 (7.0)	0.0-4.6 (0.8)	300-2257 (925)	96-816 (469)	84-520 (203)	95-302 (184)	6.0-8.2 (7.5)	0.0-4.2 (1.4)	400-1590 (895)	76-1020 (409)	84-472 (204)	40-260 (166)
	ST	6.5-8.0 (7.3)	0.0-2.8 (0.9)	360-1850 (842)	81-877 (365)	84-472 (184)	60-260 (149)	5.5->9.6 (7.4 approx)	0.0-5.3 (1.7)	247-1844 (822)	20-940 (319)	42-168 (114)	20-260 (110)
	BT	7.0-7.8 (7.4)	0.0-5.0 (1.7)	80-1882 (770)	96-496 (327)	42-208 (92)	102-220 (180)	6.4-7.9 (7.4)	0.0-4.3 (1.7)	260-1874 (762)	67-276 (183)	49-130 (84)	32-176 (87)
Winter (November-February)	NT	6.0->10.5 (7.5— approx)	0.0-1.0 (0.2)	688-2952 (918)	116-5474 (1514)	220-800 (424)	400-860 (630)	6.0-8.8 (7.4)	0.0-5.8 (2.2)	650-1540 (890)	24-1640 (888)	244-700 (343)	125-400 (380)
	ST	6.8-9.1 (7.2)	0.0-2.0 (0.3)	146-2852 (783)	30-1173 (674)	110-720 (366)	10-360 (183)	6.6-7.6 (7.0)	0.0-4.4 (2.3)	700-960 (770)	414-1115 (672)	90-500 (244)	12-350 (207)
	BT	6.9-7.5 (7.1)	0.0-2.5 (0.7)	80-1200 (742)	194-1200 (630)	192-700 (366)	131-400 (277)	7.2-7.9 (7.5)	0.0-3.0 (2.6)	450-1560 (695)	40-462 (263)	144-372 (232)	120-200 (163)
Annual (January—December)	NT	4.6->10.5 (7.3— approx)	0.0-0.6 (0.6)	43-2952 (904)	12-5474 (737)	84-980 (331)	16-860 (233)	5.6-8.8 (7.4)	0.0-5.8 (1.6)	35-1820 (858)	5-1792 (631)	84-997 (308)	17-400 (178)
	ST	6.5-9.1 (7.3)	0.0-5.7 (0.7)	28-2852 (882)	5-1293 (521)	84-720 (294)	10-360 (153)	5.5->9.6 (7.3— approx)	0.0-5.3 (1.8)	77-2100 (810)	8-1337 (475)	42-1320 (272)	12-350 (151)
	BT	6.9-7.8 (7.4)	0.0-5.0 (0.9)	80-1882 (755)	31-2243 (490)	42-1320 (280)	20-400 (205)	6.4-8.2 (7.6)	0.0-5.0 (1.9)	96-1874 (728)	2-2960 (360)	49-1210 (248)	18-230 (126)

NT — Neap tide ; ST — Spring tide ; BT — Bore tide.

TABLE 5. *Seasonal and annual fluctuations on the hydrological conditions of the Hooghly Estuary in the vicinity of sulphite pulp and paper industry near sampling station No.* 3 *(250 m below outfall) during* 1973-'74
(Range with average values in parenthesis are indicated)

	Tide	Low Tide pH	Low Tide DO (mg/l)	Low Tide BOD_5 at 20°C ±1°C (mg/l)	Low Tide $KMnO_4$ demand (mg/l) ½ hr OC at 100°C	Low Tide Alkalinity as Ca CO_3 (mg/l)	Low Tide Chloride as Cl (mg/l)	High Tide pH	High Tide DO (mg/l)	High Tide BOD_5 at 20°C ±1°C (mg/l)	High Tide $KMnO_4$ demand (mg/l) ½ hr OC at 100°C	High Tide Alkalinity as $CaCO_3$ (mg/l)	High Tide Chloride as Cl (mg/l)
Summer (March-June)	NT	7.8-8.0 (7.9)	0.0-5.6 (2.1)	3	9-440 (146)	210-308 (241)	16-25 (21)	8.0-8.2 (8.1)	0.2-3.8 (2.3)	1-5 (3)	4-52 (23)	176-260 (213)	16-25 (21)
	ST	7.8-8.0 (7.8)	0.0-4.7 (2.8)	—	5-200 (78)	168-260 (220)	24-42 (33)	8.0-8.2 (8.1)	4.2-6.6 (4.8)	2-6 (3)	4-11 (6)	148-224 (205)	20-29 (23)
	BT	7.8-8.2 (7.9)	1.5-5.6 (3.1)	5	3-152 (65)	176-374 (218)	18-43 (35)	7.9-8.2 (8.1)	3.3-6.8 (5.2)	2-6 (4)	2-8 (5)	164-286 (204)	16-22 (19)
Rainy (July-October)	NT	7.6-8.0 (7.8)	1.3-5.8 (3.6)	5-437 (152)	4-195 (80)	84-163 (115)	12-100 (47)	7.8-8.1 (8.0)	1.5-6.1 (4.4)	0-5 (3)	4.73 (18)	84-126 (106)	8-20 (16)
	ST	7.4-8.1 (7.4)	0.0-5.8 (3.7)	2-240 (150)	9-248 (59)	84-525 (114)	12-60 (34)	7.7-8.0 (7.9)	3.0-5.9 (5.1)	2-5 (3)	4-33 (16)	78-164 (106)	12-23 (16)
	BT	7.6-8.0 (7.8)	0.9-5.2 (3.8)	6-544 (147)	6-87 (38)	70-123 (91)	6-30 (19)	7.8-8.1 (7.9)	2.6-6.3 (5.3)	0-5 (2)	3-49 (14)	59-123 (88)	8-20 (15)
Winter (November-February)	NT	7.4-9.0 (7.9)	0.0-5.6 (3.8)	6-840 (402)	27-177 (130)	101-320 (231)	25-40 (32)	7.5-8.1 (7.9)	3.4-7.1 (4.8)	0-89 (44)	2-240 (54)	130-293 (207)	20-20 (20)
	ST	6.6-7.9 (7.6)	0.0-5.8 (3.8)	5-240 (32)	20-117 (99)	145-420 (224)	10-19 (15)	7.6-8.0 (7.9)	0.0-7.4 (5.2)	2-76 (30)	4-111 (49)	96-300 (176)	12-20 (15)
	BT	7.5-8.0 (7.7)	1.4-5.0 (4.0)	4-92 (31)	16-116 (51)	134-312 (207)	20-30 (25)	7.8-8.2 (8.0)	0.0-7.5 (5.3)	5-28 (16)	2-125 (34)	144-298 (176)	20-30 (24)
Annual (January-December)	NT	7.4-9.0 (8.9)	0.0-5.8 (3.1)	3-840 (216)	4-440 (131)	84-320 (191)	12-100 (35)	7.5-8.2 (8.0)	0.2-7.1 (3.9)	0-89 (36)	2-240 (41)	84-293 (166)	8-25 (18)
	ST	6.6-8.1 (7.6)	0.0-5.8 (3.2)	2-240 (85)	5-248 (122)	84-525 (184)	10-60 (29)	7.6-8.2 (7.9)	0.0-7.4 (4.9)	2-76 (32)	4-111 (36)	78-300 (158)	12-29 (18)
	BT	7.5-8.2 (7.6)	0.9-5.6 (3.4)	4-544 (76)	3-152 (51)	70-374 (177)	6-43 (27)	7.8-8.2 (8.0)	0.0-7.5 (5.2)	0-28 (7)	2-125 (17)	59-298 (158)	8-30 (19)

NT — Neap tide ; ST — Spring tide ; BT — Bore tide.

and 7.8-8.2 during LT and HT respectively (Table 6).

Station No. 5 (1.05 km below outfall)

Similar trend in DO and BOD were found to be maintained at this stretch as noted at 750 m downstream. On an annual average basis, a slightly higher values of OC were indicated during NT (LT) compared to HT of all the tidal phases. Chloride ranged between 8-30 mg/l and between 6-31 mg/l during LT and HT respectively. Alkalinity was in the range of 67-321 and 67-312 mg/l during LT and HT respectively and higher values were recorded during NT. pH values during LT and HT were in the ranges of 8.0-8.2 and 7.9-8.2 respectively (Table 7).

Plankton population

Annual average values indicated a lower trend during NT (LT) compared to ST and BT (Table 8).

Current velocity

The annual trend indicated lowest velocity (48.4 cm/sec) during NT compared to ST and BT. The extent of lateral dispersion of the pollutants was maximum (37.1 m) during NT (Table 9).

DISCUSSION

The study of the dynamic conditions in the estuary induced by the tidal currents and phases in different seasons is of great significance and relevance in the assessment of the fate of pollutants discharged into the system. Importance of such study has also been emphasised by Pritchard (1967). Ghosh *et al.* (1976, 1977, 1978) indicated a significant influence of certain physical parameters, like nature of tides, tidal phases and flow of the Hooghly estuary on the degre eof pollution caused by pulp and paper mill wastes. Low DO, high organic load as reflected by BOD and OC, dispersion of pollutants to a wider area (av: 43.7 m) due to comparatively more sluggish current velocity (av. 24.7 cm/sec) and low plankton density were indicated particularly during neap tidal phase under LT. Similar findings were also reported by Ghosh *et al.* (1976, 1977, 1978).

It is significantly evident that the adverse environmental conditions were reflected during NT (LT), as it is indicated from highest % reduction (90) in DO and maximum % gain (23099) in BOD (Table 10) at the outfall. No recovery of DO and BOD was felt within 1.05 km below the outfall during NT (LT), whereas a tendency to recover was indicated at 1.05 km downstream during HT condition of all the tidal phases. OC recovered at 750 m below only during HT condition of ST and BT and at 1.05 km downstream during HT of NT which is a clear indication of longer retention of the pollutants during NT particularly under low tide condition.

Moreover, adverse condition in pH was also apparent during NT(LT) as the upper limit was recorded to be high at the outfall (pH > 10.5) and at 250 m below (pH 9.0). It was also reflected in the annual trend at 250 m below as indicated by high average pH during NT (8.9) compared to ST and BT. The LT condition was inferior to HT at 750 m below, since the upper limit of pH was found to range between 8.5 and >10.5 during LT compared to 8.0-8.8 during HT. Although recovery of alkalinity took place at 750 m below during all the tidal phases under HT condition, it remained affected during NT under both LT and HT conditions even 1.05 km below.

Summer condition reflected much inferior environmental situation compared to winter as indicated by high BOD in summer (av: 1117 mg/l) at the outfall the trend of which is also indicated even at 1.05 km below.

DO was lower in summer (0.6-5.9 mg/l) compared to winter (0.4-8.0 mg/l) at a stretch

TABLE 6. *Seasonal and annual fluctuations on the hydrological conditions of the Hooghly Estuary in the vicinity of sulphite pulp and paper industry near sampling station No. 4 (750 m below outfall) during 1973-'74*
(Range with average values in parenthesis are indicated)

	Tide	Low Tide						High Tide					
		pH	DO (mg/1)	BOD_5 at 20°C ±1°C (mg/1)	$KMnO_4$ demand (mg/1) ½ hr OC at 100°C	Alkalinity as $CaCO_3$ (mg/1)	Chloride as Cl (mg/1)	pH	DO (mg/1)	BOD_5 at 20°C ±1°C (mg/1)	$KMnO_4$ demand (mg/1) ½ hr OC at 100°C	Alkalinity as $CaCO_3$ (mg/1)	Chloride as Cl (mg/1)
Summer (March-June)	NT	7.8-8.1 (8.0)	0.6-5.9 (3.2)	—	3-120 (59)	184-297 (238)	16-31 (24)	—	—	—	—	—	—
	ST	7.8-8.1 (8.0)	2.2-4.9 (3.3)	— —	4-72 (35)	154-319 (226)	31-44 (38)	—	—	—	—	—	—
	BT	7.9-8.2 (8.0)	2.6-5.6 (3.8)	—	4-33 (12)	172-277 (215)	19-30 (23)	—	—	—	—	—	—
Rainy (July-October)	NT	7.6-8.1 (7.9)	3.6-6.3 (4.0)	0-86 (46)	4-37 (22)	84-136 (109)	12-40 (26)	8.0-8.0 (8.0)	4.2-5.3 (4.7)	0-39 (19)	7-8 (8)	88-136 (108)	8-21 (14)
	ST	7.7-8.1 (7.9)	1.5-6.0 (4.1)	5-66 (42)	5-72 (21)	84-164 (108)	12-26 (18)	7.8-7.9 (7.9)	4.0-5.5 (4.7)	3-5 (4)	6-7 (7)	83-130 (104)	12-14 (13)
	BT	7.8-8.1 (8.0)	3.8-5.3 (4.5)	2-65 (38)	5-56 (20)	67-123 (98)	6-20 (14)	7.9-8.1 (8.0)	3.3-5.8 (4.9)	1-40 (11)	5-10 (7)	46-130 (93)	8-12 (9)
Winter (November-February)	NT	7.7-8.5 (8.0)	3.1-6.4 (4.7)	0-60 (28)	4-260 (106)	110-380 (242)	20-20 (20)	7.9-8.0 (7.9)	5.0-5.5 (5.2)	1-10 (5)	30-176 (103)	160-215 (187)	20-20 (20)
	ST	7.8-8.0 (7.9)	3.6-8.0 (5.0)	0-8 (5)	18-32 (26)	124-298 (213)	18-20 (19)	7.9-8.1 (8.0)	6.2-7.5 (6.6)	3-5 (4)	4-7 (5)	120-304 (183)	12-20 (16)
	BT	7.6-8.0 (7.8)	0.4-5.8 (5.1)	0-11 (4)	56-340 (100)	60-336 (216)	20-30 (27)	7.9-8.2 (8.0)	5.6-8.4 (6.8)	2-4 (3)	0-18 (8)	105-212 (183)	20-30 (25)
Annual (January-December)	NT	7.6-8.5 (8.0)	0.6-6.4 (4.2)	0-86 (35)	3-260 (55)	84-380 (183)	12-40 (23)	7.9-8.0 (8.0)	4.2-5.5 (5.0)	0-39 (10)	7-176 (40)	88-215 (146)	8-21 (16)
	ST	7.8-8.1 (7.9)	1.5-8.0 (4.4)	0-66 (29)	4-72 (30)	84-319 (177)	12-44 (24)	7.8-8.1 (7.9)	4.0-7.5 (5.7)	3-5 (4)	4-7 (6)	83-304 (146)	12-20 (14)
	BT	7.6-8.2 (7.9)	0.4-5.8 (4.6)	0-65 (26)	5-340 (52)	60-336 (170)	6-30 (21)	7.9-8.2 (8.0)	3.3-8.4 (5.7)	1-40 (8)	0-18 (8)	46-212 (146)	8-30 (14)

NT — Neap tide ; ST — Spring tide ; BT — Bore tide.

TABLE 7. *Seasonal and annual fluctuations on the hydrological conditions of the Hooghly Estuary in the vicinity of sulphite pulp and paper industry near sampling station No.5 (1.05 km below outfall) during 1973-74*
(Range with average values in parenthesis are indicated)

	Tide	Low Tide						High Tide					
		pH	DO (mg/l)	BOD_5 at 20°C ±1°C (mg/l)	$KMnO_4$ demand (mg/l) ½ hr OC at 100°C	Alkalinity as $CaCO_3$ (mg/l)	Chloride as Cl (mg/l)	pH	DO (mg/l)	BOD_5 at 20°C ±1°C (mg/l)	$KMnO_4$ demand (mg/l) ½ hr OC at 100°C	Alkalinity as $CaCO_3$ (mg/l)	Chloride as Cl (mg/l)
Summer (March-June)	NT	8.0-8.2 (8.1)	4.1-5.9 (4.6)	1.3-4.9 (3.2)	2-17 (8)	168-230 (199)	16-23 (20)	8.1-8.2 (8.2)	4.6-6.0 (5.2)	0.3-4.0 (2.9)	2-7 (5)	136-231 (197)	16-23 (20)
	ST	8.0-8.2 (8.1)	3.4-6.0 (4.7)	2.7-3.4 (3.1)	3-15 (7)	154-229 (186)	19-21 (20)	8.0-8.2 (8.1)	4.6-6.3 (5.4)	2.0-5.0 (2.7)	2-11 (5)	156-229 (192)	20-31 (24)
	BT	7.9-8.2 (8.1)	3.6-5.6 (4.9)	1.0-5.3 (2.9)	5-7 (6)	146-297 (179)	18-24 (20)	8.0-8.2 (8.1)	3.9-6.0 (5.5)	1.9-5.3 (2.4)	2-7 (5)	152-297 (191)	16-22 (19)
Rainy (July-October)	NT	8.0-8.2 (8.1)	4.6-6.0 (5.5)	1.3-3.7 (2.7)	4-14 (7)	84-135 (115)	8-28 (15)	8.0-8.2 (8.1)	4.0-6.5 (5.5)	0.4-4.5 (2.4)	3-12 (6)	84-139 (105)	12-22 (14)
	ST	8.0-8.2 (8.1)	4.6-6.2 (5.5)	1.2-5.3 (2.6)	2-10 (6)	83-164 (108)	10-20 (13)	7.9-8.2 (8.1)	2.6-6.8 (5.6)	0.6-5.7 (2.4)	2-7 (5)	78-176 (100)	12-20 (14)
	BT	8.0-8.2 (8.1)	5.1-6.6 (5.5)	1.3-4.8 (2.4)	3-15 (7)	67-123 (94)	8-12 (10)	8.0-8.2 (8.1)	4.5-6.7 (5.5)	1.3-5.5 (2.3)	2-14 (6)	67-104 (84)	6-17 (11)
Winter (November-February)	NT	8.0-8.2 (8.1)	1.6-7.2 (5.8)	1.2-4.1 (2.7)	4-26 (12)	120-293 (209)	20-20 (20)	8.1-8.2 (8.1)	5.1-7.8 (6.5)	1.0-4.8 (2.4)	2-16 (9)	120-293 (205)	20-20 (20)
	ST	8.0-8.2 (8.1)	4.8-8.0 (6.4)	0.7-6.0 (2.2)	3-21 (9)	120-321 (202)	12-20 (16)	8.0-8.2 (8.1)	4.5-8.0 (6.5)	2.2-4.6 (2.2)	5-12 (8)	120-312 (204)	11-20 (16)
	BT	8.0-8.2 (8.0)	0.2-8.8 (6.7)	1.3-8.7 (2.1)	6-15 (7)	144-288 (201)	20-30 (23)	8.0-8.2 (8.1)	4.4-8.8 (6.8)	0.8-6.2 (1.9)	0-14 (7)	134-272 (200)	18-30 (23)
Annual (January-December)	NT	8.0-8.2 (8.1)	1.6-7.2 (5.4)	1.2-4.9 (3.9)	2-26 (17)	84-293 (185)	8-28 (18)	8.0-8.2 (8.1)	4.0-7.8 (5.6)	0.3-4.8 (3.6)	2-16 (6)	84-293 (168)	19-23 (17)
	ST	8.0-8.2 (8.1)	3.4-8.0 (5.6)	0.7-6.0 (3.5)	2-21 (12)	83-321 (163)	10-21 (16)	7.9-8.2 (8.1)	2.6-8.0 (5.7)	0.6-5.7 (3.0)	2-12 (6)	78-312 (156)	11-31 (18)
	BT	8.0-8.2 (8.1)	0.2-8.8 (5.9)	1.0-8.7 (3.0)	3-15 (10)	67-297 (161)	8-30 (17)	8.0-8.2 (8.1)	3.9-8.8 (6.3)	0.8-6.2 (2.6)	0.14 (6)	67-297 (144)	6-30 (17)

NT — Neap tide ; ST — Spring tide ; BT — Bore tide.

TABLE 8. *Annual effect on plankton population (number/litre) in the vicinity of a sulphite pulp and paper mill located on the bank of the Hooghly during various tidal phases of low (LT) aud high (HT) water leavel.* (Range with average values in parenthesis are indicated)

Sampling Zone	Tide	January—December (LT)			January—December (HT)		
		Phyto	Zoo	Total	Phyto	Zoo	Total
1 (750 m above outfall)	NT	6—45 (19)	1—43 (12)	7—75 (31)	6—25 (13)	3—36 (19)	8—50 (32)
	ST	5—73 (20)	2—69 (16)	8—75 (36)	10—32 (19)	8—51 (20)	20—67 (39)
	BT	8—117 (38)	4—54 (18)	12—160 (56)	5—13 (39)	8—106 (24)	7—169 (63)
2 (Outfall)	NT	2—3 (3)	0—4 (2)	3—6 (5)	0—8 (2)	0—9 (3)	0—20 (5)
	ST	5—12 (8)	2—7 (5)	8—17 (13)	0—11 (5)	0—26 (11)	0—27 (16)
	BT	0—11 (7)	0—46 (12)	2—57 (19)	3—25 (10)	3—29 (12)	6—34 (22)
3 (250 m below outfall)	NT	2—10 (6)	1—7 (3)	4—17 (9)	0—43 (12)	0—13 (6)	5—46 (18)
	ST	2—16 (7)	0—10 (4)	4—24 (10)	2—25 (11)	1—21 (11)	6—36 (22)
	BT	5—33 (13)	3—66 (20)	10—76 (33)	1—4 (2)	8—58 (33)	9—62 (35)
4 (750 m below outfall)	NT	5—17 (11)	2—3 (2)	7—20 (13)	0—9 (5)	2—43 (16)	2—46 (21)
	ST	5—19 (12)	1—26 (10)	6—45 (22)	4—18 (12)	2—52 (30)	6—66 (42)
	BT	6—32 (19)	0—30 (18)	6—62 (37)	3—27 (17)	6—70 (30)	9—80 (47)
5 (1.05 km below outfall)	NT	2—27 (10)	0—57 (21)	8—84 (31)	7—24 (15)	8—64 (36)	16—88 (51)
	ST	4—31 (13)	6—101 (44)	9—105 (57)	4—61 (28)	2—68 (38)	16—122 (66)
	BT	6—40 (15)	4—240 (45)	10—280 (60)	4—72 (40)	3—77 (29)	12—131 (69)

NT—Neap tide ; ST—Spring tide ; BT—Bore tide ; LT—Low tide ; HT—High tide

TABLE 9. *Influence of tidal phase on certain physical parameters of the Hooghly Estuary during low water level in the vicinity of a sulphite pulp and paper mill near Hazinagar during* 1973-'74 (Range with average values in parenthesis are indicated)

Period of observation	Current velocity (cm/sec)			Lateral spread of the coloured waste water (cm)		
	NT	ST	BT	NT	ST	BT
Summer (March-June)	22.0—27.5 (24.7)	39.7—63.1 (51.4)	32.0—50.6 (41.3)	1678—5490 (4366)	915—2898 (2352)	732—1647 (1350)
Rainy (July—October)	55.8	37.5—64.1 (56.8)	24.7—79.3 (52.7)	763—3050 (1881)	610	1372
Winter (November-February)	61.9	35.7—61.0 (48.3)	48.8—87.5 (68.1)	610—7168 (2898)	1220	610—3721 (2250)
Annual (January—December)	22.0—61.9 (48.4)	35.7—64.1 (53.1)	24.7—87.5 (57.1)	610—7168 (3711)	610—2898 (1982)	610—3721 (1914)

TABLE 10. *Effects of tidal phase on the annual trend of the physico-chemical conditions reflected as % reduction (—) or % gain (+), of the Hooghly estuary in the vicinity of a sulphite pulp & paper industry near Hazinagar outfall data has been taken as Standard)*

Place of study (Sampling station)	Tide	DO	BOD_5	$KMnO_4$ demand (½ hr OC)	Alkalinity
Above outfall (1)	—	—	—	—	—
Outfall (2)	NT (LT)	—90	+23079	+14640	+97
	NT (HT)	—72	+22479	+ 4407	+88
	ST (LT)	—88	+23011	+10320	+76
	ST (HT)	—69	+22400	+ 3554	+74
	BT (LT)	—86	+22779	+ 9700	+71
	BT (HT)	—71	+21354	+ 3500	+68
250 m below outfall (3)	NT (LT)	—46	+ 5438	+ 2520	+14
	NT (HT)	—33	+ 847	+ 193	+ 1
	ST (LT)	—46	+ 2261	+ 2340	+10
	ST HT)	—17	+ 789	+ 177	+ 1
	BT (LT)	—46	+ 2203	+ 920	+ 8
	BT (HT)	—25	+ 112	+ 70	+ 6
750 m below outfall (4)	NT (LT)	—28	+ 797	+ 1000	+ 9
	NT (HT)	—14	+ 163	+ 186	—12
	ST (LT)	—25	+ 706	+ 500	+ 6
	ST (HT)	0	+ 11	— 54	— 6
	BT (LT)	—28	+ 688	+ 940	+ 4
	BT (HT)	—12	+ 142	— 20	— 1
1.05 km below outfall (5)	NT (LT)	— 7	+ 2	+ 240	+10
	NT (HT)	— 3	— 21	— 57	+ 2
	ST (LT)	— 5	— 16	+ 140	— 2
	ST (HT)	— 3	— 16	— 54	0
	BT (LT)	— 7	— 9	+ 100	— 2
	BT (HT)	— 3	— 9	— 40	— 2

NT—Neap tide ; ST—Spring tide ; BT—Bore tide ; LT—Low tide ; HT—High tide.

of 750 m below, which was also indicated at 250 m below. Higher values of alkalinity and OC were noted in summer at 250 m below. The inferior conditions during summer months were also reported in the Hooghly estuary by several workers (Ghosh *et al.*, 1976, 1977, 1978, 1979). During the summer months, predominance of the flood tide over ebb tide and considerable reduction in the freshwater discharge might be the reasons for the pollutants being trapped in the estuarine system for a longer time, which was also reported in the Thames estuary (Mohanrao, 1972) and Eems estuary (Eggnik, 1967).

Plankton population was adversely affected by the trade effluent at the outfall indicating occasional absence of phytoplankton and zooplankton during all the tidal phases of LT and HT. LT condition was more unfavourable as evident from non-recovery of phytoplankton even at 1.05 km below the outfall, whereas a distinct recovery was noted during HT of all the tidal phases.

Neutralisation of the acidic and alkaline wastes discharged from various process units of the integrated mill, removal of organic suspensoids particularly from pulp unit to reduce BOD load, elimination of taste and odour producing substances to protect the aesthetic quality of the receiving water, by-product recovery and re-cycling of the waste water are some of the important measures need to be taken for abatement of pollution. Steps may be taken to discharge the waste waters particularly during ST and BT under HT condition when effect of pollution is less. Since the estuary receives pollutants from major industries, it is necessary to treat each type of effluent to maintain suitable water quality to develop coastal aquaculture around the estuarine and coastal belt.

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STUDIES ON FAECAL COLIFORM IN AN ESTUARINE ENVIRONMENT OF PORTO NOVO

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ABSTRACT

Escherichia cloi, an enteropathogenic, peritrichous flagellated, Gram-negative, motile bacterium associated with contaminated water and food has been documented as the etiologic agent causing gastroenteritis and urinary infection particularly in children. The presence of this faecal coliform in aquatic system, fishery products and other sources is considered as an index of sanitary quality and as an indicator of pollution. The study on the occurrence and distribution (following swabbing and MPN methods) of faecal coliforms and *E. coli*, in water, sediments, plankton, finfish and shellfish in different zones of Vellar Estuary at Porto Novo revealed that sewage sludge material has contaminated extensively. The relationship of this organism with other environmental parameters and importance of enteropathogenic *E. coli* associated with finfish, shellfish, plankton, water and sediment in the estuarine environment are discussed.

INTRODUCTION

THE RECOGNITION of the fact that intestinal microflora of human origin could directly reflect the purity criteria of natural waters opened new vistas in the science of ' Indicator systems '. Ever since the pioneering effort of Escherich (1885), faecal coliforms have been increasingly used as indices of water quality in sanitary microbiology and form a measure of human encroachment and interferences. The presence of coliform-organisms in a given environment has been attributed to the influxes of allochthonous bacteria from waste discharges and surface water drainages (Morrison, and Fair, 1966 ; Geldrich, 1967 ; Weidner *et al.*, 1969 ; Evans and Owen, 1972 ; Carney *et al.*, 1975 ; Faust, 1976). It is now well known that survival of coliform bacteria in an estuary depends on physical, chemical and biological conditions of the aquatic environment (Hendricks, 1972 ; Faust *et al.*, 1975) and their change in concentration depends mainly upon the rate of dilution in a tidal estuary (Ketchum *et al.*, 1952).

Studies on the distribution of faecal indicator organisms in tropical estuarine environment are limited (Ludwig, 1975; Owen, 1978) and very little information is available on this aspect in Indian waters (Raveendran *et al.*, 1978). This lacunae formed the impetus for the present study and the main objectives were to explore the qualitative and quantitative concentration of coliform in a tropical tidal estuary.

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Material and Methods

Sample site and collection of samples

Monthly collections were conducted at three stations *viz.* marine, gradient and tidal zones (Fig. 1) of Vellar Estuary, Porto Novo (Lat. 11° 30′ N, Long 79° 46′ E) from April to September 1979. Surface and bottom water samples were collected using aseptic procedures in presterilized 500 ml glass bottles and Meyors water sampler respectively. The sediment was sampled using Peterson grab and a portion was sub sampled aseptically. Plankton samples were collected using a No. 20 (76 μ) horizontal plankton net and were aseptically transferred to presterilized wide mouth tubes, fish, prawn, crabs originating from estuarine environs were also collected by operating cast net, while samples of molluscs were collected using a dredge and all were aseptically transferred to unused polythene bags. The samples were brought to the laboratory in an ice box. Preference was given to average sized, commercially important species with no visible sign of deterioration, injury or disease. All bacteriological examinations were carried out within two hours after collection.

Physical and chemical parameters

Salinity was estimated following the standard argentimetric method (Harvery, 1955) with necessary corrections. The temperature was measured using a centigrade thermometer and pH by a Elico-Model L1-10 pH meter. The light penetration was measured by a secchi disc of 30 cm diameter. Winkler's method was used to estimate the dissolved oxygen content.

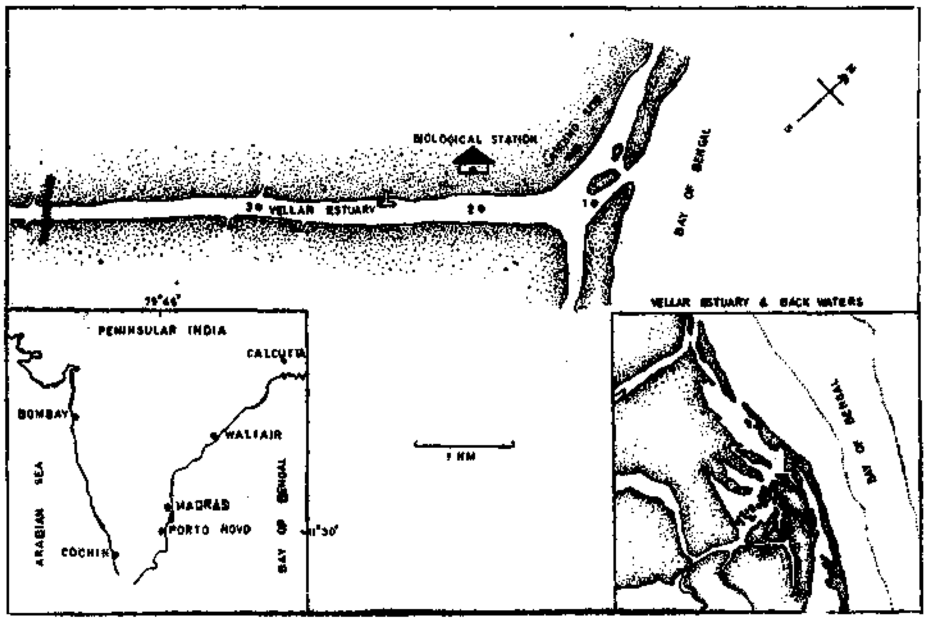

Fig. 1. Vellar Estuary and the Stations selected for the study.

Bacterial enumeration

The total coliform (TC) bacteria were determined by the MPN method, using 3 tubes of tryptone-lactose broth for each dilution, and the elevated temperature test in estimating faecal coliform (FC) densities (APHA, 1971). The gas producing bacterial isolates which showed metallic sheen on EMB agar were further purified and IMViC series of test were performed on the selected isolates for *Escherichia coli.*

Fish, prawn and crabs were washed with sterilized water to remove the adhering sand and detritus particles. First, the external surface was swabed using sterile cotton swabs. Subsequently, the entire gill surface was swabed. An incision was then made in the vent region by a sterilized scissors and the exposed rectum was swabed. The swabs were inoculated in 10 ml tryptone-lactose broth and incubated at 37°C—The presence of TC, FC and *E. coli* were confirmed as cited above. MPN were computed from standard APHA (1971) Tables.

Results

Total coliform bacteria

Coliform bacteria were consistently isolated throughout the period of study. Counts of Total Coliform (TC) and Faecal Coliform (FC) fluctuated seasonally and spatially from Station 1 to 3. The total coliform counts in surface waters varied from 4 to 1500/100 ml in Station 1, 9 to 2400/100 ml in Station 2 and 7 to 2900/100 ml in Station 3 (Fig. 2) On the other hand, the TC counts in bottom waters varied from 28 to 1500/100 ml, 7 to 1500/100 ml and 4 to 1600/100 ml in Stations 1, 2 and 3 respectively (Fig. 2). Poor counts of total coliform were recorded during May in Station 1 and during April in Stations 2 and 3. Generally high counts were noticed in the month of June and September in all the stations both in the surface and bottom waters. The total coliform counts were found to be decreasing from the upper reaches of the estuary (Station 3) to the mouth (Station 1). While in the sediments, total coliform counts varied between 21 and 1600/gm in Station 1, 20 and 2400/gm in Station 2. and 9 and 2900/gm in Station 3 (Fig. 3). Here also, the same trend of fluctuation of TC counts were observed as in the water column. The TC counts decreased after the peak during June and after a decline during July and August another peak was noticed during September in all the stations invariably. Plankton samples always harboured maximum number of TC as compared to water and sediment samples in all the three stations. Total coliform concentration varied from 1100 to 2900/gm in Station 1, 1500 to 9500/gm in Station 2 and 1100 to 4400/gm in Station 3 (Fig. 3). Seasonal fluctuation in TC in plankton completely differed from that of water and sediment samples. Maximum counts were recorded during August in Station 1 and 3 and during July in Station 2.

Faecal coliforms

Comparatively, the FC counts were found to be much lower than TC counts in all the stations. In the surface water, the FC population generally varied from 0 to 240/100 ml and the maximum numbers were seen during June in all the stations (Fig. 2). In the case of bottom waters, maximum number of 120/100 ml was observed in July in Station 1 and the minimum of 1/100 ml was recorded in April in Station 2. Generally high counts of FC were noticed in Station 3. Whereas in the sediment, the density varied from 0 to 29/gm in Station 1 ; 4 to 29/gm in Station 2 and 0 to 12/gm in Station 3 (Fig. 3). Comparatively, the population was lower than the water samples in all the stations. Maximum numbers were noticed during May in Stations 1 and 2 and during June in Station 3. The occurrence of FC in plankton fluctuated to a greater extent (Fig. 3). The maximum numbers were recorded in July in all the stations and the range was found to be between 0 and 95/g of plankton. When an average count of FC in water, sediment and plankton was considered, the maximum numbers were observed during June in the case of surface water, during July in plankton and bottom water and during May in sediment. A significant irregularity occurred in MPN values. Among

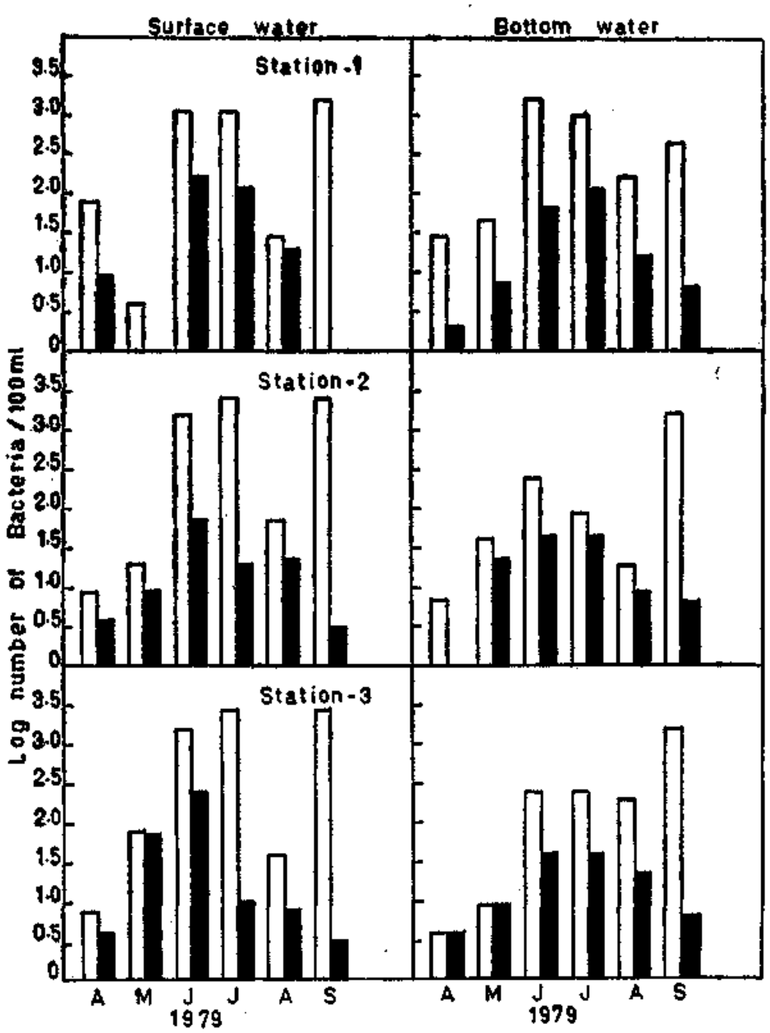

FIG. 2. Seasonal variation in the distribution of total and faecal coliform in surface and bottom waters of the three Stations.

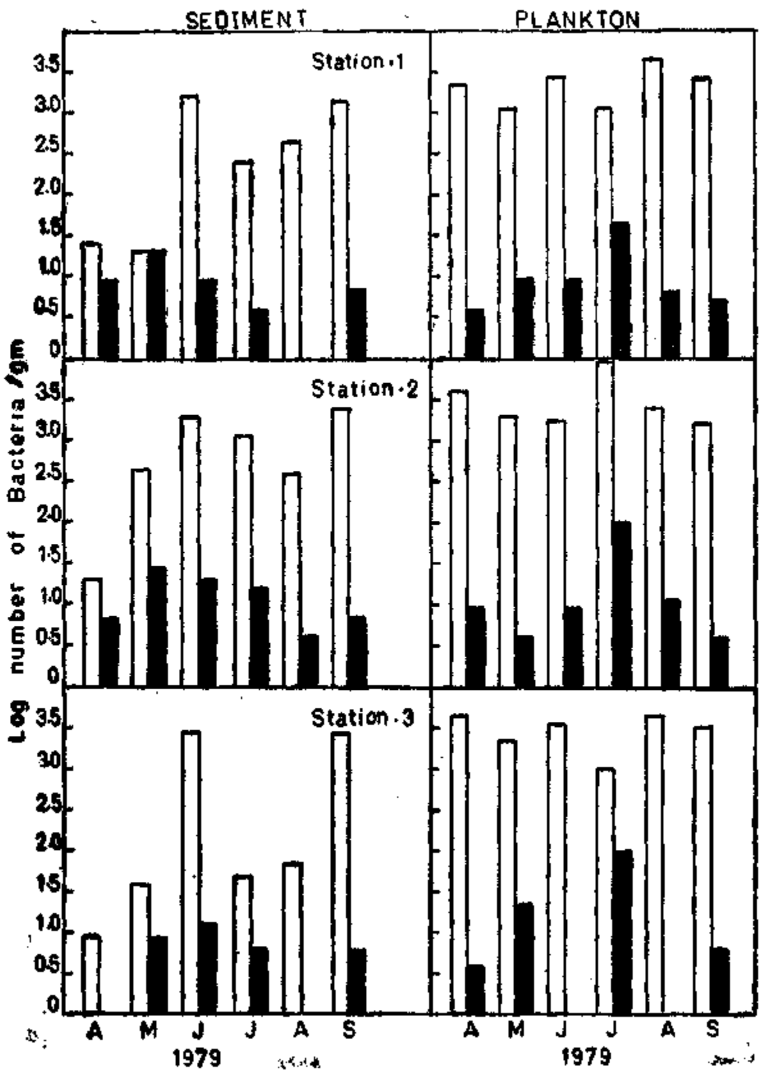

FIG. 3. Seasonal variation in the distribution of total and faecal coliform in sediment and plankton samples of the three Stations. □ Total coliforms and ■ faecal coliforms.

the three stations, total FC population during the whole period of collection was highest in Station 3.

The IMViC types for 510 Ec+cultures were determined and the results showed that the faecal coliform group isolated from water, sediment, plankton, finfish and shellfish from different zones consisting of 83.72% of *E. coli* (Table 2). The non-faecal origin, *Enterobacter aerogenes* were very low (15.49%). In the present study, 4 isolates (0.59 & 0.20%) belonging to the intermediate groups were also encountered.

Incidence of TC and FC in finfish and shellfish

The occurrence of TC and FC in finfish and shellfish is shown in Table 1. Totally 218 economically important species of fish, prawn, crabs and molluscs were examined, out of which 87 (92.55%) were found to harbour coliform. Among the 62 species of fish examined 58 (93.55%) were positive coliforms. All the samples of prawn and molluscs were found to be contaminated with TC. In the case of crabs as much as 50% of the samples was found contaminated with TC. All samples collected from fish landing site were found to

TABLE 1. *Incidence of total coliform and faecal coliform associated with various groups*

Area collected	Groups examined	No. of specimens examined	No. of Samples positive: Total coliform	Faecal coliform
Estuary	Fish	62	58 (93.55)	30 (48.39)
	Prawn	12	12(100)	10 (83.33)
	Crab	6	3 (50)	3 (50)
	Mollusc	14	14(100)	8 (57.14)
	Total	94	87 (92.55)	51 (57.45)
Landing site	Fish	50	50(100)	40 (80)
	Prawn	50	50(100)	44 (88)
	Crab	24	24(100)	16 (66.67)
	Total	124	124(100)	100 (80.65)

TABLE 2. *Classification of EC + cultures isolated in total* (510 *isolates*)

Classification		IMViC types	Total numbers	% of the total
Faecal origin*				
Escherichia coli	..	+ + − −	414	
	..	− + − −	11	
		+ − − −	12	83.72
Nonfaecal origin	..	− − + +	67	
Enterobacter aerogenes	..	− − − +	12	15.49
Intermediate	..	± + − +	3	0.59
		+ + − +	1	0.20
		− + + +	0	

* Parr (1938) : Classification of IMViC reactions, indole, methyl red, Voges-Proskauor and sodium citrate test.

harbour TC (Table 1). Similarly FC in the estuarine organisms were found to be less (57.45%) than from fish landing site (80.65%). Prawns and molluscs in the estuarine environs yielded more FC (83.33% and 57.14% respectively) followed by crab (50%) and fish (48.39%). In general a high incidence of TC and FC was recorded in the landing site than in the Vellar Estuary. However at the landing site FC were found mainly in the surface and gill regions of fish whereas in the estuary it was equally found in all the regions including the faecal matter of the fish collected from the estuarine environment.

Discussion

Coliform organisms have been used as indicators of the sanitary quality of water for over 70 years. These indicator organisms find their way into the estuary either directly by the disposal of sewage water or indirectly through the canals. It is interesting to note that, the coliforms and faecal coliforms were found to be decreasing from Station 3 (upper reaches of the estuary) to Station 1 (mouth of the estuary) of the Vellar Estuary. Similarly Faust (1976) has observed high TC and FC levels at the Muddy Creek stations between 5.4 to 45 km points on the Rhode River axis and their numbers rapidly declined towards the mouth of the river. Also, the coliform counts were generally higher in the surface waters than in the bottom waters. This could be due to the detrimental effect of salinity on the distribution of these indicator organisms. Similarly, Goyal *et al.* (1978) have reported low counts in the high saline waters. The maximum counts of (2900/100 ml) coliforms observed in Station 3 may be due to the entry of Buckingham Channel water into the estuary, which is highly polluted by human effluents. Next to this, the coliform counts in Station 2 was comparatively lower than Station 3. At Porto Novo, no proper sanitary facilities exist and majority of the population are in one way or the other, in continuous contact with the estuary and backwater thus explaining the high TC and FC counts. Night soils from latrines which are periodically disposed in the estuary is the prime reason for the very high counts observed in Station 2.

The TC and FC were found in higher numbers in bottom sediments than in overlying bottom and surface waters in all the stations. Our results conform with the findings of Raveendran *et al.* (1978) in Cherai beach, Carney *et al.* (1975) and Kapar *et al.* (1979) in Rhode River and of Goyal *et al.* (1978) in Galveston Bay, who have shown high coliform counts in sediments.

During the present study, high coliform population was observed in plankton samples. According to Shimidu *et al.* (1971) most bacteria in seawater are believed to be attached to plankton and other small particles in the seawater and this could probably be the reason for the high counts of coliforms as observed in this study. It has also been demonstrated by Kaneko and Colwell (1978) that the life-cycle of *Vibrio parahaemolyticus* an enteropathogenic halophile, was predetermined by its association with zooplankton especially copepods. However, further investigations are essential to clearly explain the positive association of coliforms to plankton.

The incidence of TC, FC and *E. coli* in finfish and shellfish examined affirms a certain degree of the bacterial pollution at Porto Novo environs, since coliforms do not constitute the indigenous flora of these estuarine organisms. The occurrence of coliforms and *E. coli* in finfish and shellfish were earlier reported by Panduranga Rao and Gupta (1978), Premjith (1979) and Iyer and Pillai (1971). It is interesting to note that, all the samples examined from the landing site harboured coliforms while in freshly caught finfish and shellfish from the estuarine environment was much lower (55 to 92%). This may be because of the unclean transportation and unhygenic handling practices. Fishes which were caught in the marine environment are brought to the landing site for sale. Here they are kept in unclean baskets and also mixed with estuarine catch. These types of practices alongwith favourable temperatures may be the primary reasons for the high isolation rate at the landing site. Also the coliform contamination was mostly observed in the body surface and gill regions of the fishes from landing site and in all the regions in the estuarine fishes.

The results of IMViC test (Table 2) indicate that faecal coliform group EC + isolated showed a complete domination of *E. coli* of faecal origin. The present study was supported by earlier investigations of Sayler *et al.* (1975) who reported 79% of *E. coli* from estuarine. sediments, 82.3% in marine sediments by Babinchak *et al.* (1977), 87% in frozen foods by Fishbien *et al.* (1967) and 96.69% in 11 different habits by Warren and Bennoit (1977). The incidence of *E. coli* in Belgion sea Board at Ostend, Knokke and Koksijde (Kufferath, 1970), in Michigan lake (Selleck, 1970), in streams of Pennsylvania (Glantz, 1973), in Ebrie lagoon (Pages, 1975) in the coastal zone in Coguimbo (Salas, 1976) was reported and stated that *E. coli* are the indicator species of faecal pollution.

The results of the present study bring to light the widespread occurrence of coliforms in the Vellar Estuary. Although the numbers were below the standard density (van Donsiel and Geldrich, 1971), it is imperative to improve the existing sanitary facilities at Porto Novo. Apart from this the high isolation rate of coliforms from commercially important shellfish and finfish samples is a note worthy revelation and it is prime importance to assess the microbiological quality of seafoods before consumption. The present study is a preliminary account and it clearly indicates that a systematic study over a period of time is essential to postulate the seasonal fluctuation of coliforms in a typical estuarine environs.

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HOLOTHURIAN TOXIN AS A POISON TO ERADICATE UNDESIRABLE ORGANISMS FROM FISH FARMS

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ABSTRACT

Eradication of predators and undesirable organisms from fish ponds and farms is an important operation in any culture practice. Hitherto various chemicals and extracts from plants are being used for this purpose. For the first time, a toxin extracted from the holothurian, *Holothuria atra* (Jaeger) was tried with success. When used in limited water volume eradication was thorough and complete. Not only fishes but other organisms such as molluscs, crustaceans and polychaetes were found to be affected by the toxin. Experiments conducted in a rock pool at Port Blair (Andamans) and in a tidal pool at Mandapam camp are discussed in detail.

INTRODUCTION

PREDATORS and undesirable organisms pose a serious problem in culture operations. Several methods are in vogue to remove them before stocking the ponds on farms. The simplest method is to net them out. Unfortunately by this method the weeding is not complete. Several kinds of chemicals are used in ponds and farms for controlling undesirable fishes. The control chemicals can be grouped as plant derivatives, chlorinated hydrocarbons and organophosphates. Of all the chemicals chlorinated hydrocarbons are most toxic to fishes (Jhingran, 1975). Shirgur (1975) has listed several poisons of plant origin, the chief being Derris powder which is extensively used to weed out fishes and other organisms. Smith (1947) and Frey (1951) have stated that holothurian toxin is used in some places for fishing.

In this paper the results of the experiments conducted in a rock pool at Port Blair (Andamans) and in a tidal pool at Mandapam Camp are presented.

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Some holothurians have a toxin known as holothurin in their bodies. The defensive mechanisms of toxins of some tropical holothurians have been discussed by Bakus (1968), The holothurians release the toxin when disturbed and this serves as defensive mechanism for the otherwise softbodied defenceless animals. Holothurin is a saponin (steroid glycosid). found in four of the five orders of the class Holothuroidea. It may be highly concentrated in the body wall, viscera, Cuvierian tubules. The concentration of holothurin varies according to the seasons. Holothurin appears to have a direct effect on muscle contraction. It has also a nerve blocking effect similar to that of cocaine and physostigmine in laboratory animals. Holothurin is considerably stronger than the most powerful haemolytic reagent saponin and probably enters fishes through gills. It is stated that fresh water fishes are more resistant to holothurin than are marine fishes probably because gills of the latter are less permeable (Bakus, 1974a). Bakus (1974b) has proposed a hypothesis that toxicity in tropical holothurians probably evolved in part as a chemical defense mechanism against predation by fishes. Bakus and Green (1974) have also discussed the geographic pattern of toxicity of sponges and holothurians.

Holothuria atra is one of the most common holothurians in the Indian region. It is abundant both at Andamans and on the South East coast of India around Mandapam. It is numerically abundant when compared to other species of holothurians. This species which does not find any use in *Beche-de-mer* in India can be used for the extraction of toxin to weed out fishes.

Extraction of Toxin

Extraction of toxin from holothurians is relatively simple affair. When *Holothuria atra* is handled the toxin is released as a burgandy coloured liquid from the body wall. For every hundred holothurians one bucket full of sea water is used for the extraction of the toxin. The holothurians are taken one by one and gently rubbed all over the body with hand inside water. About 200 CC of toxin is extracted from hundred holothurians. The holothurian is in no way affected by the extraction of the toxin this way. The holothurians used in the experiments at two places ranged in length from 110 to 300 mm. The toxin from 100 holothurians will make one bucket full of sea water red in colour and the extraction takes about an hour. After extracting the toxin the holothurians are kept in a corner of the pond in which the toxin has been poured. In this way the holothurians are kept alive and can be used again since they regenerate the toxin again. Also small quantities of the toxin continue to be discharged from those which were handled for toxin extraction. While no irritation or pain is felt when the toxin is handled with bare hands it was observed that continuous handling of toxin for three or four days make the outer skin of the palm peel off at some places.

Experiments

The experiments conducted in rock pools at Port Blair is first described. During low tide big rock pools are exposed. One such rock pool was selected near the Government College at Port Blair. The area of the rock pool was 16 square metres, with the depth of water at 0.75 metres. The toxin extracted in the manner described above and poured into the rock pool. One hour after the release of the toxin small fishes like *Ambassis urotaenis* were found to move to the edge of the rock pool. In this state they can easily be removed by hand net. At the same time some big fishes like *Pseudopristipoma nigra* were found to swim weakly at the surface of the water. Two hours later many of them were found to be dead, the bigger ones being more susceptible. Four hours later all most all fishes including crabs, molluscs and polychaete worms were found to be dead. It was found that some large mullets at the bottom of the rock pool were not affected till the tide came up again. However at Mandapam Camp when the toxin was used in a tidal pool all the mullets which were small in size were also affected and died. This experiment was repeated several times in the same rock pool and the fishes collected on one particular occasion are listed below. The figures in the parenthesis indicate the number of fish collected under each species.

Ambassis urotaenia Bleeker (132 Nos.)

Pseudopristipoma nigra (Cuvier) (4 Nos.)

Acanthurus gahm (Forskal) (3 Nos.)

Callyodon dussumieri (Valenciennes) (2 Nos.)

Tetrodon spp. (2 Nos.)

Cheiloprion labiatus (Day) (2 Nos.)

Daya jerdoni (Day) (2 Nos.)

Chaetodontops collaris (Bloch) (1 No.)

Siganus javus (Linnaeus) (1 Nos.)

Siganus vermicularis (Valenciennes) (4 Nos.)

At Mandapam Camp a small tidal pool near the fish farm was selected for the purpose of testing the toxin. The area of the tidal pool was more or less same as that of the rock pool at Andamans. Toxin extracted from 100 holothurians was poured into the tidal pool at 10 A.M. Two hours later when the tidal pool was visited it was seething with life with hundreds of fish coming to the surface and performing gyrating movements. The holothurians for the experiment were collected from Mandapam Camp and were more or less of the same size as those used at Port Blair. Several fish were also found at the edge of the pool as noticed at Port Blair and four *Tilapia mossambica* were found dead. Six hours after the release of the toxin there was no sign of life in the pool. All fishes were found dead and settled to the bottom. More than 75% of the dead fish were retrived from the pool the same evening by hand picking and the rest which were floating next day were collected by hand net. The weeding was thorough and complete. In the tidal pool where the toxin was tested only *Tilapia mossambica*, *Mugil waigiensis* and *Liza macrolepis* were found. Exactly 910 *Tilapala mossambica* weighing a little over 5 kg and ranging in length from 45 to 93 mm and 29 mullets weighing 90 g and ranging in length from 41-49 mm were collected from the tidal pool.

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EXPERIMENTAL FIELD CULTIVATION OF *GELIDIELLA ACEROSA* AT ERVADI IN INDIA

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ABSTRACT

The red seaweed *Gelidiella Acerosa* is the principal Agarophyte utilized in agar agar Industry in India. The natural reserves which are limited are also reported to be depleating, posing a threat to existance of the dependent industries. The need for cultivating the sea weed was recognised as early as 1973. Since then a technique has been developed and is practised in the field on a large Experimental scale as a sponsored project of M/s. Cellulose Products of India Ltd., with the Central Salt and Marine Chemicals Research Institute.

INTRODUCTION

THE technique for its field cultivation was developed earlier at Krusadai (Subbaramaiah, *et al.*, 1975, Patel, *et al.*, 1978, 1979) and was adopted later to the coastal open shore environment at Ervadi. The cultivation method employs bottom culture of the vegetative fragments on coral stone substrata. The detailed methodology and the initial results were reported earlier (Patel, *et al.*, 1979). This paper deals the more recent findings of the cultivation (January 1978-79) with a final evaluation in relation to making it self-sufficient.

The growth and agar agar yield data are given in Table 1. The maximum length of the plants and the maximum cover of the crop attained were 12 cms in month of January 1979 and 60% in months December '78 and January '79 respectively. In all 4 harvests were made, two for each planting generally after six months growth period. The maximum crop yield of 122 g/m^2 was obtained in III harvest of the second phase planting. For this set of experiments maximum growth rate reached was 3.17 g/g/month. Higher growth rate of 3.6 g/g/month was seen in the IV harvest of the first phase planting. This works out to about 22 fold increase over the seed material on a six monthly harvest. Six monthly harvests have been found to give greater over-all crop yield in comparison with yearly harvests. The agar content and gel strength on the average varied from 22-23% and 385-395 g/cm^2 respectively. The maximum values for agar content 24%, and gel strength 450 g/cm^2 were recorded during June in the year 1979 and compares well with the naturally grown material. However, the crop yield is higher in January harvest only. It would appear that the quality of agar improved subsequent to the period of greater growth rate which may be from January to June.

So far on an over-all basis of a total crop yield of 260 g/m^2 dry was obtained in the field cultivation experiments during the three years (87 $gms/m^2/year$). However a maximum

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TABLE 1. *Growth and agar agar yield data*

Phase of planting I & II	No. of harvest III & IV	Extent Sq. m.	Period of growth		Range of monthly growth rate g/month	Crop yield g/m^2		yield of agar mean	gel strength g/cm^2 mean
			From	To		range	average		
I	III	116.4	Jan. '78	Jan. '79	0.8 —2.02	62—114	76	23	395
I	IV	,,	Jan. '79	July '79	1.16—3.61	53— 75	64	—	—
II	III	392.46	July '78	Jan. '79	1.54—3.17	82—122	89	22	385
II	IV	,,	Jan. '79	July '79	1.25—2.82	45—68	64	—	—

annual crop yield of 190 gms/m^2 was obtained in 1978-1979.

Our future efforts will be to increase the crop yield three fold by further research and farm management techniques.

With an investment of 10 lakhs of Rupees, the returns from a 5 hectare farm project at the rate of 24.0 tons (at Rs. 12000 per tonne) per year would work out economically viable, paying for itself from the second year onwards.

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AQUACULTURE IN COASTAL ZONE : CONSTRAINTS AND REGULATIONS

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ABSTRACT

This paper examines the constraints and benefits of aquaculture in the coastal zone. Water being the most vital element of all human uses, a balance must be struck between the different priorities of the use of water to get the greatest social and economic benefit. The various constraints that deter the rational development of aquaculture in the coastal zone include legal and riparian rights, effluent regulations, oil and energy developments besides the territorial zone regulations. Recent developments in regard to the 200 mile Economic Zone off India's Coastal Zone, have also an impact on the coastal aquaculture.

In regard to the containment of pollution or establishing the effluent standards some acts are promulgated in India, but they are not in active regulation. Various acts such as the International river improvement Act ; the navigable waters protection Act ; the Environment Act ; the Environmental contaminants Act, and the Fisheries Act under active application in other countries are examined to study their efficacy to protect aquaculture in the coastal zone. It is necessary that the rights of aquaculture be protected as much as the rights of agricultural activities.

It is proposed that a national policy on aquaculture be recommended, the guidelines for which must be formulated on the basis of investigations suggested in the present paper and more detailed case studies.

INTRODUCTION

THE TECHNOLOGIES developed by the research institutes of the country now make aquaculture an economically viable operation. Several private entepreneurs and industrial organizations are showing a keen interest in this new field of business enterpreneurship.

However, stepping up coastal aquaculture requires a long range planning, commensurate with and complementary to, other coastal zone uses, of market developments and of progress made in the country to maintain water quality standards. Much of our present preoccupation of aquaculture nature is concerned with its technological development—not on the social, political and management aspects. For a long range planning, however, both have to be developed together in order to interrelate and fix a priority for aquaculture as a coastal zone use of this country.

A viable aquaculture plan viz., which includes laws and regulations, should have a comprehensive definition of the coastal zone. For this purpose a coastal zone can be comprehensively defined as an area intermediate to land and deep seas wherein heavy impact is felt by all uses made of areas adjacent to it, both inland and towards sea ; where the impact of point sources of pollution is the greatest. This area, immediately adjacent to coastal waters upto high water mark may be comprised of several independent ecological systems such as marshes, swamps, mangroves, mudflats, creeks estuaries, inlets, beaches and dunes all, actually sensitive to and adversely affected by man's activities. These activities concern land use development, reclamation, dredging, filling, mining, agricultural activities and so on; Activities concerned with multipurpose river basin developments have a profound effect on the coastal ecology.

Taking all these into consideration, a study is made in this paper on the direction the aquaculture development should take in this country, what laws are to be developed and enforced. In order to do this, some of the environmental laws promulgated in other countries such as USA are examined. Other possible constraints to aquaculture developments in the coastal zone and the regulations that are required to be made into legislations are also discussed.

A national policy on aquaculture is the need of the moment when India is going in for an all-comprehensive development of its coastal zone consequent to its declaration of 200-mile extended Economic Zone.

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Present Directions of Aquaculture Growth in India and Possible Directions of Future Growth

Present growth of aquaculture

The types of current coastal aquaculture practices in India are as follows:

The present Indian farming practices thus are extensive and are land intensive in the sense that they expand the acreage requirements. Raft and cage culture do not compete for coastal space if they are in a small degree. Still, if the marketing technology for oyster and mussel is developed and an international marketing system opens up or a consumer preference develops in the domestic market, large parts of the bays and lagoons would be used for this culture. Shrimp culture, which is now confined to a small acerage consisting of enclosed ponds and impoundments, or backwaters, would require extensive acerage for the highly expanding markets. A single shrimp farm can use an acerage of 100-200 ha of enclosed bays, lagoons or marsh land provided sufficient seed is available. Developing technology including the bio-engineering developments, is a factor which can restrict the competition for aquaculture space in future. Thus with the present trend towards high density rearing using the recirculating water systems, laboratory rearing and nursery management of almost all culturable coastal species of fish and shell-fish may become feasible. Then, species such as lobsters which command high prices and have ready markets would also be cultured in tiered cages and such high density systems.

All the systems have one common requirement and that is, clean waters.

Physical types
(Brackishwater practices)

Lakes	Backwaters	Bheries (impoundments)	Estuarine	Farms	Coastal	
Near sea mouths	Extended several kms upland depending on tidal amplitudes and distances the tide travels.		Extend along the regions of tidal incursion.	Extend 50-60 km up from river mouths	Hatcheries	Farms on Bays, Or Lagoons and coast itself.

Biological types

High density cultures (Rafts and cages)	Wild practices (Bheries, Backwaters)	Semi intensive or semi-controlled
Experimental farms of research Institutes or corporations.	Salt pans of private entrepreneurs.	Privately owned farms.

Possible lines of future expansion of aquafarming

In addition to the conventional practices for shrimps, fish, Oysters, seaweed *etc.*, other types of farming would come up in future. The possible future expansion could be as follows :

(i) Stocking of natural waters with seed produced in hatcheries ;

(ii) Coastal marine farms which enclose vast expanses of water, acting as marine zoos ;

(iii) Underwater marine parks where certain deepwater forms and marine mamals can be maintained in vast enclosures ;

(iv) Artificial reefs created with waste materials such as tyres or waste construction material to create suitable niches, for the marine animals ;

(v) Aquaculture in thermal effluents ;

(vi) Expansion of coral reef activities : protecting the reefs from the present sedimentation and inflow of polluted waters ;

(vii) Expansion of pearl culture activities ;

(viii) Expansion of seaweed parks as a source of drugs and other industrial products and of energy.

CONSTRAINTS TO COASTAL AQUACULTURE

Some pollution-abatement laws and their application to coastal aquaculture

A great number of pollution abatement laws have had to be promulgated in highly industrialised countries such as USA to control environmental degradation. These laws are applicable to degradation of both air and water and hence can be examined in relation to aquaculture.

Relevant Acts of U.S.A. applicable to Aquaculture.

Environmental Acts

—The National Environment Policy Act 1964.

—The Environment Containments Act.

—The Federal Water-pollution Act 1972, amended in 1975.

The National Environmental policy Act 1964 requires that all administrative agencies give full consideration to environmental effects in planning and conduct of their envisaged programmes 'recognizing the critical importance of restoring and maintaining environmental quality to the overall welfare and development of Man. The Environment Contaminants Act or the Federal Water Pollution Control Act 1972 primarily put limits on the emissions to air, effluents to water and hence, generally expect the contaminators to have pollution abatement systems (secondary or tertiary treatment systems in case of municipal wastes) incorporated into their construction plans. In other words, to restore the integrity of the waters. Industry-wise effluent standards were fixed (Anon, 1975).

Navigable waters acts :

The other acts which have a bearing on the aquaculture use of the coastal Zone are :

—The International River Improvement Act ;

—The Navigable Waters Protection Act ;

Both acts one again, concern the waters which are the 'life lines' to Aquaculture. Although envisaged to take care of the shipping, dredging and erosion problems, of the construction of dams and other improvements to rivers and naviation with the nation's waterways and those rivers which pass the boundaries of adjacent nations ; once again the laws enacted would be useful to protect the aquaculture uses —because the rivers open into the coastal zone.

All these laws as applicable to Indian scene pertain to the requirement of 'clean' water as they pass down from streams and rivers to the estuary and thence to the coastal zone and inshore areas where the aquaculture farms are established. The federal water pollution control act of 1972 envisages such objectives as " best practicable control technology currently available " (BPCTCA) for industry, a uniform minimum level of secondary treatment for all municipalities ; special procedures to control dumping of dangerous substances, those which pollutes the drinking water ; A special list of ' Toxic Pollutants ' are given ; the industrial clean-up standards include recycling requirements. The standards to be maintained include those for BOD (Biological Oxygen Demand) suspended solids ; fecal coliform counts and pH level (acidity). Putting this act into effect has become an immence problem even for U.S.A.

Fisheries Acts : The fisheries acts require protection of fish habitats for maintaining the recreational and commercial fishing industries. These acts insist on the necessity for early consultation with fisheries officials before any consultations or work related to water use are undertaken. The fisheries acts also require effluent regulations to be developed on an industry to industry basis and in co-operation with states and industries.

Water quality control Act, India ; As regards India, the country is just coming up with gross statistics of industries located along the estuarine shorelines, the effluent loads released into waters and the level of treatment standards these posess. The water (Prevention and control of pollution) Act of India was introduced in 1974 and since then many states are reported to have adopted (Chowdhuri, 1979 ; Government of India, 1974). This scheme envisaged a survey of and zoning of rivers ; A classification of rivers, lakes, estuaries, coastal waters and ground water ; A ' water use ' map was introduced and 200 monitoring stations are identified. Sewerage and sewage treatment is also receiving attention.

According to a 1965 estimate (Pakrasi, 1965) there are about 151 ' Bheris ' or impoundments used for brackishwater aquaculture in the Sundarbans area of West Bengal lying between the river Hooghly on west and Ichamati on the east. These normally take in water from the creeks, canals or estuary itself, as per their location. Those lying adjacent to the Kulti estuary *i.e.* the major outfall area of Calcutta city's sewage and, those along the sewage canal itself take the raw sewage directly into their farms as a fertilizer. This is one major area of study for the application of clean water act in the sense that a dilution standard and treatment level of sewage, the health hazards involved in using raw sewage are areas of immediate attention. Ray and Pakrasi (MS) estimate a total sewage discharge of 160 million gallons/day into the Kulti estuary.

The discharge of untreated wastes from about 95 factories (pulp, rayon, acid and other factories) along a 90 km stretch of Hooghly estuary is of the order of 252 million gallons/day (Ghosh *et al.* 1973). According to a 1967 estimate of FAO (FAO, 1967), this estuary is one of the most polluted estuaries in India. Yet this estuarine system is highly productive in terms of seed of all commercially cultivable species, *viz. Penaeus monodon, P. indicus, Metapenaeus brevicornis, Palaemon styliferus* among shrimps ; *Liza parsia, L. tade, L. macrolepis* among mullets ; others such as *Lates calcarifer, Elops, Megalops, Eleutheronema tetradyctylum,* and so on ; highly productive in terms of fish and prawns harvested from the bheris and ponds. Thus aquaculture can be termed as a high priority use of this particularly coastal zone.

Other type and sources of pollutants that cause constraints to Aquaculture Development

Offshore developments : Some of the principal offshore developments are the explorations, mining and dredging activities on the continental shelf, in the territorial zone, the location of thermal plants, tapping tidal energy *etc.* Oil exploration and energy developments are considered as a national priority.

However, it is necessary that the environmental changes that occur in the wake of these developments are kept track of. The thermal plants require great quantities of cooling water; they release back heated water into the coastal water or enclosed creek where they are located. This raises the ambient water of the area which, if it happens to be taken into an adjacent farm, would result in kills or irreversible changes. However, a good feature of thermal effluents is that they can be quantified (unlike oil pathways from sludges and sewages).

All activities concerned with hydrocarbons gave a specific effect on coastal farms. Occurrence of oil spills in off shore waters, and the entry of direct oily waters into the coastal farms might be a remote chance. But, those which cause real harm are spilled from ships, harbours, ports, refineries or by dumping: The persistant action of these, besides the physical harm caused by them, are also being documented now through various global agencies (Portmann, 1976). The capacity of shellfish to accumulate trace metals, yet another type of pollutant, in their tissues has been well documented (WHO, 1979). Fortunately, in this context, India has not gone in yet for extensive commercial oyster farms in the coastal areas.

Non-point sources of pollution: This, probably, is the most pervasive pollution problem unidentiafible in nature. It is defined as one resulting from nearly every type of human activity and land use. In U.S.A. those are regulated through the Clear Water Act Amendments of 1977 administered by the Environmental Protection Agency. Agricultural sources include run off from manure disposal areas, land use for livestock, silviculture activities etc., among others (Ischinger, 1979).

The major constraint posed by all these pollutants to aquaculture, which are only briefly outlined above, is the urgent requirement of monitoring the water quality that enters the farms. This is real and major constraint because India does not yet possess the capability to monitor all these pollutants in the waters and, managers of coastal aquaculture farms would be hard put to do the same.

Other constraints

Effective Use rights: These include rights of ownership of property by law or those rights that accrue from prolonged or customary use. As long as the technology of development is low these rights of ownership might not arise; but, increasing level of technology and higher rate of returns from the farms would cause this problem of property rights.

Legal problems: An examination of some of the legal problems which might pose a big constraint to coastal aquaculture is also essential.

The main constraint is that there is practically no legal protection to the coastal aquaculturist. If there is any little legal protection, the administration of it might be very much diffused divided between a large number of departments *viz.* forest, irrigation, municipality, river development boards, Agriculture departments, port authorities and even Railways. A few examples can be shown.

A traditional seed collection ground may slowly disappear by land filling and construction activities of port authorities, or by railways or some other body. The fish farmer has very little say in this matter nor has he a means of redress since he does not own the seed grounds or the high-water canals that transport the seed.

In locating and operating of hatcheries one absolute requirement is, that the intake pipe should be located in a site free of debris, pollutants and sediments. If an industry is located in any adjacent areas, its effluents would certainly influence the intake water ; the hatchery operator has no protection because the sea water is a " Common property " resource and he does not pay ' water costs ' to the Government.

A third type is the construction of pens and cages. At present these are not allowed in public waters such as waterways and territorial seas. However, if at a future date such concessions are given in protected bays, lakes or lagoons, management problems, such as construction of rafts, piers *etc*. would arise. Here also legal problems connected with ' Common property ' resources would arise. Further, the release or pumping out metabolite-filled waste-water from the farm itself might result in contamination of surrounding waters or eutrophication of the same.

Conflicts with other users of the same zone such as commercial fishermen, sport fishing, swimming, boating, etc. are bound to arise.

Riparian rights also prohibit water course contamination to the detriment of the downstream user. This could also cause legal constraints of aquaculturist when the metabolite-filled waters are released out from his farm ; or a fish disease from his farm spreads to other areas.

Regulations

The foregoing pages have explained all the possible constraints that can presently be envisaged to aquaculture in coastal zone. Using those as a base, some regulations which are now in force in other departments of the Central and State Governments and those which are required to be made are discussed here.

Water use

The main regulation is the impartial regulation of water use. A coordinated policy is required to govern this important basic need. The development should be regulated so that the user and non-user do not have clash of interests.

Some sort of licensing or taxing system also is to be developed similar to the water cess in the agricultural irrigation system, so that the coastal farmer will use the water in proportion to his need ; secondly he would regulate release of metabolite-filled effluent of his farm to outside.

Regulations for clean water

The environmental laws, the water pollution control acts and fisheries Acts are all primarily for clean waters for drinking, swimming and to keep the air clean. These laws would also help to see that waters which farmer gets are partially treated, with low coliform counts (of sewages), do not contain lethal levels of trace metals or toxic chemicals which may not kill the fish but might cause harm to man. A day might come when the farmer might have to defend himself legally when fish from his farm are the cause of harm to some human consumer.

Incorporation by law into coastal zone uses of the country

With the rising awareness of the critical importance of the coastal zone uses, aquaculture might require to be incorporated as one of the important multiple uses. (Rajyalakshmi, Ms). The question of compatibility comes in then. For example, in the forest land region fish and timber can be treated mutually compatible crops. The main requirement here would be maintaining water quality standards to protect the fish habitat. However, in some coastal forest regions the topography of the land is such that the slopes are unstable, high rate of sand dune formation, high rate of soil erosion, all of which cause environmental damage. This can be set right by technological (engineering) applications. Timber harvesting in the bordering area can be suspended also to save the fish farm. It is also necessary that a quantification of values of fish farming vs timber production at this area be done to fix the areas of adjustment.

Similarly, as long as disease monitoring is maintained, a law to this effect would protect the Aquafarmer and his industry.

A National policy on aquaculture

It is high time that the nation develops a policy on aquaculture to select and delimit areas of priority use for aquaculture in coastal zone; to prevent indiscriminate water and land use programmes which deter the progress of aquaculture; to protect the aquaculture farms from pollution by fixing standards and monitoring; to have proper item-wise development of species and marketing pattern; to keep standards of fish and prawn quality; to develop a system for quick dissemination of developing technologies to farmers through advisory bodies; and to monitor funding participation of *Govt.* and ICAR Institutions, Universities, corporations and other private bodies and societies.

Promotion of co-operatives or societies

Fish farmers can also form themselves into a sort of associations, or unions to claim-reparations for damages to property (Fish stocks, constructions such as pens, cages) caused by oil spills from offshore accidents; or sedimentation by mining and other dredging activities of other industries and such physical obstructions.

Bio-engineering systems could be encouraged to conserve space, reduce dependency on natural waters, develop high density systems; techniques which will make aquaculture reduce its extensive type of operation but make it more intensive.

Conclusions

What is needed to expand aquaculture, quite apart from technology, is the regulations for protection of the industry.

Aquaculture as a semi-controlled practice has been going on for a long time, most notably in the backwater systems of Kerala and the 'bheris' of West Bengal, While high hopes are held for all-round expansion of coastal aquaculture, as stated earlier, it may remain static unless both regulations and technology go hand in hand.

Just now there is a diffusion of efforts regarding technological developments in coastal aquaculture. Several agencies, institutes, corporations and private industries and MPEDA have conducted this research within their own frame work. While attempts are being made to avoid duplication or overlap, it is necessary that more attention is paid to the serious gaps. For instance, all technology cannot be geared to the development, marketing and export. The major part of the technology should be geared towards site-location, water quality maintenance/monitoring; protection to aquaculture users from other use such as the coastal sitings.

Comprehensive planning system is the most essential thing of the moment. Not only state by state planning, but all maritime states should come together for the purpose, set norms and priorities so that adequate funding can be provided for development of aquaculture without restrictions from other uses of coastal zone. A Zonal Council could be formed to take care of the problems and regulations and a National Policy evolved to lay policies and legislations.

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MARINE POLLUTION — ITS EFFECTS ON LIVING RESOURCES WITH SPECIAL REFERENCE TO AQUACULTURE

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ABSTRACT

Due to large scale industrialisation and indiscriminate discharge of effluents with high BOD, toxic chemicals and particulate matter reach the aquatic environment, either directly or indirectly. Enrichment of the coastal waters through nutrients and minerals lead to immediate and long term effects on the biota and fishery resources causing severe eutrophication or mass mortality. Among a large variety of pollutants which reach the aquatic environment, the domestic sewage, agricultural pesticides, industrial wastes, oil and oil dispersants, radioactive wastes and the polluted water from the coconut retting zones causes deliterious effects in the inshore and fish farming areas.

The paper documents the effects of pollution on the aquatic environment and the biota as well as the fishery resources especially in the fish farming areas. The toxic industrial effluents and their effect on the planktonic algae and zooplankton together with the effects of organochlorine compounds on the growth, survival and reproduction of cultivable organisms and the stress they produce on the ecosystem are also discussed.

INTRODUCTION

THE EMPHASIS in recent years has been to augment fishery resources through large scale coastal aquaculture in estuarine and contiguous low lying areas. The open seas are also chosen for sea farming of shellfishes. When development projects are aimed at increasing food production, the discouraging factor that could offset this aim is the pollution of the inshore, estuarine and coastal waters connected by river systems. Rivers have been described as the greatest instruments of marine pollution and the main action of the river borne pollutants is in estuarine and coastal waters which are the most vulnerable aeas from the point of aquaculture and fisheries.

Most of the protein food harvested from the marine and estuarine environment are subjected to varying degrees of environmental pollution. When pollution is heavy, these organisms can be destroyed or rendered inedible or if consumed become a cause of human ailment. Some of the major pollutants that cause havoc to aquaculture systems are sewage, industrial effluents containing heavy metals and toxic chemicals, pesticides, hydrocarbons, dredged soil and thermal pollution.

The rapid growth of industries in India since independence, especially in major coastal urban areas, have steadily deteriorated water quality in the estuarine and coastal environment. The major areas are Bombay-Kalyan, Calcutta-Asanol Durgapur area, Madras, Vizakhapatnam, Udyogamandal near Cochin and Chaliyar near Calicut. It is estimated that there are at present 670 textile mills, 1600 tanneries, 600 sago and starch mills, 180 sugar mills, 77 distilleries, 25 nitrogenous fertilizer factories, 125 dairies and other units discharging untreated or partially treated waste waters into the aquatic environment (Shastri,1979). The river systems which receive these industrial pollutants have suffered considerable degradation over the years and whenever mass mortalities of fish occur the public attention has been drawn. But, what has gone unnoticed is the long-term effect of these pollutants such as destruction to spawning grounds, prevention of migratory fish and genetic isolation of certain species.

Apart from the effects on the ecosystem by pollutants in the natural aquatic environment, there are also practical considerations for aquaculture. Perhaps even more important than in the natural environment, water quality is vital in aquaculture. A major threat to the entrepreneurs in aquaculture is disease to the cultivable organisms. This threat can be aggravated by adverse water conditions which impose a threat on the cultured animal. Pollutants invariably contribute towards increase of stress to the organisms. Other than the adverse effects, the vital question of product acceptability is also closely linked to the problems of water quality in aquaculture.

In view of the emphasis given to aquaculture in recent years, the Central Marine Fisheries Research Institute has taken up investigations to identify the sources of pollution, monitoring the major pollutants and studying the lethal and sub-lethal effects on finfishes and shellfishes including their larval forms. This paper is aimed at reviewing and discussing the results of investigations carried out in different areas and the possible effects of common pollutants on the cultivable organisms.

INDUSTRIAL EFFLUENTS

The major pollutants which can pose serious threat to aquaculture are from pulp and paper industry, fertilizer and chemical industries. It is estimated that 250,000 to 350,000 litres of waste water will be discharged for every tonne of paper that is produced. For example, the pulp division of the Gwalior Rayons Factory at Calicut discharges 75 million litres per day. The combined effluents from the Udyogamandal industrial area discharged into Periyar River is estimated at 172 millions litres per day. These effluents contain a variety of toxic substances such as mercury, zinc, copper, cadmium, lead, fluorides, ammonia, urea and chlorine apart from radioactive materials, oil and grease, etc. Some of these substances are directly toxic while others are indirectly harmful due to their decomposition or oxidation by chemical or biological action. Once any of these industrial effluents reaches the culture systems it can seriously affect the quality of the cultured products and cause reduction in the yield.

Whether released to air, water or soil, significant amounts of heavy metals are eventually carried into estuarine and coastal water systems. Heavy metals important trace components of the sea water, may function in both the regulation and stimulation of biological processes. Some metals have known biological functions such as copper, zinc, manganese, magnesium, etc. and are required in varying concentrations for growth and metabolism of all organisms. Many of these metals are found in organisms in concentrations that are high in comparison to the surrounding medium. Hence, the biota concentrate many heavy metals relative to their environment. The invertebrates appear to have a particularly high capacity for concentrating metals from the environment when they filter plankton during feeding. Because of the ability of many metals to form complexes with organic substances, there is a tendency for them to be fixed in the tissue and not to be excreted. Some of these elements have no apparent biological function and it appears that organisms have little capability for selective uptake or excretion. Such metals may not be toxic to the host organisms, such as zinc or copper in oysters, but they may be passed up the food chain to higher organisms including man.

The bioaccumulation of metals varies from metal to metal and differs among the various organisms. Some of these metals are bioaccumulated through the food chain, so that predators have the highest concentrations. Studies of uptake by the mussel *Mytilus edulis* of Zn, Mn^{54}, Co^{58} and Fe^{59} showed that the principal accumulation of these metal radionuclides occurs through the food and the transfer directly from the water is relatively minor (Pentreath, 1973). Bioaccumulation of copper by oysters and other invertebrates has been known for a long time. Copper tends to give the oysters not only green colour, but a rather unpleasant metalic taste. While the concentration of copper in sea food has never been considered a serious threat to human health, the marketing of such sea food is seriously affected. However, considering the impact of these biological accumulation on the organism itself the possible sublethal effect such as on neurophysiology, enzyme activity, endocrinology, parasitology and disease, and carcinogenic and mutagenic effects as well as other impacts at the cellular levels have to be taken into consideration.

Most common form of organic pollution is due to the presence of carbohydrates, fats, proteins and other organic substances found in sewage and dairies and food processing and tanning industries. For the assessment of these pollutants the BOD test is commonly used which gives the oxygen consumption of the effluent at 20°C. The ISI has set a limit of 100 mg/l for the industrial effluents and 5 mg/l for shellfish and commercial fish culture. The oxygen demand will increase by blooms of noxious algae which may further deteriorate the dissolved oxygen content of the waters. A study of the diurnal variation of the dissolved oxygen content of such polluted waters may reveal anoxic condition during the pre-dawn period in culture systems. Extreme vigilance is required under such conditions.

Apart from the deoxygenation, residual chlorine in excess of 1 ppm and presence of ammonia in excess of 1.2 mg/l or lowering of pH due to discharge of acids are some of the causes of frequent mass fish mortalities in the estuarine waters. Silas and Pillai (1976) reported an instance of mass fish mortality in the Udyogamandal-Cochin area. About 15 species of fishes and shellfishes were collected which consisted of both pelagic as well as demersal forms. The pH (4.8) clearly indicated that the pollutant was acid and acidemia caused instant death to the entire fauna in the vicinity. They also observed large scale fish mortality in another area of the Cochin Backwater caused by the effluents from a fertilizer factory. On a day of severe pollution the water sample showed the following features; temperature 30°C; dissolved oxygen 0.86 ml/l; pH 8.18; alkalinity 842.8; ammonia 333 mg/l. Incidentally, the ISI standard of tolerance limit for ammonia is 1.2 mg/l (maximum) for marine coastal waters.

Jayapalan *et al.* (1968) studied the effects of effluent discharge from a fertilizer factory in this area and stated that 'the effluent discharges from the factory directly flows into the river water'. These effluents affect the normal physico-chemical nature of the river water at various places in different ways. They observed the annual variation in pH was from 4.7 to 9.5 at various points from the immediate vicinity of the discharge towards downstream.

SEWAGE

Extensive studies on the distribution and seasonal cycles on the indicator bacteria carried out in Cochin Backwater and the inshore environment have revealed the occurrence of numerous genera such as *Pseudomonas*, *Aeromonas*, *Acromobactor*, *Flavocacterium*, *Vibrio*, *Streptococcus*, *Hemophilus*, *Micrococcus* and enterobacteriaceae. Table 1 gives the seasonal variations of total coliforms, faecal coliform and faecal streptococci in the sediments of the Cochin Backwater along with faecal index.

TABLE 1. *Occurrence of bacterial pollution indicator organisms (form 10³/gm) in the Cochin Backwater sediments for the period February 1974 to January 1975 together with faecal index*

Months		Total coli	Faecal coli	Faecal Strepto-cocci	Faecal index FC : FS
January	..	51.74	20.93	27.35	0.76
February	..	58.35	34.22	7.42	4.61
March	..	—	—	—	—
April	..	86.72	10.42	2.05	5.08
May	..	79.77	17.65	6.13	2.87
June	..	88.63	10.54	0.17	6.20
July	..	53.16	35.50	7.50	4.73
August	..	63.69	30.08	7.05	4.26
September	..	46.40	39.21	14.37	2.72
October	..	—	—	—	—
November	..	45.92	27.85	26.35	1.06
December	..	52.60	27.03	20.36	1.32

The high values of total bacterial counts are recorded during the post-monsoon period. Faecal coliforms are also found to be abundant in the post-monsoon period. The faecal index values (above 4) indicate that during certain months the sources of pollution is from human waste. It has also been observed that sandy sediments harboured more pollutional organisms which may be released upon resuspension following dredging and other activities. The ISI has prescribed the following limits for bacteria in the aquatic environment.

Tolerance limits for

Bathing, recreation, shellfish and commercial fish culture and salt manufacture	Harbour water
Coliforms MPN index per 100 ml, max. 1000	2500

OIL POLLUTION

Oil Pollution of the marine and estuarine environment can occur from a variety of sources such as accidental spills from tankers and off-shore wells, nearshore ship operations, urban and industrial sewage effluents and transported through the atmosphere. However, chronic low level contamination of localised areas originates primarily from the discharge of oil from nearshore ship operations and from industrial and sewage effluents. The direct lethal effects of oil pollution on fauna and flora have been extensively studied from nearshore waters. However, sublethal effects such as food-chain alteration and reduced resistance to environmental stress have received very little attention. It is already known that certain hydrocarbon fractions are remarkably stable in the marine environment and these hydrocarbons may detrimentaly affect the feeding responses of lobsters (Blummer *et al.*, 1973). Marine fishes and crustaceans respond to the chemical stimuli induced by oil pollution which triggers numerous kinds of behavioural response including feeding. Sub-lethal level of crude oil on lobsters have been observed to bring in changes in the sensing movements, feeding behaviours and gill operation (Blummer and Sass, 1972).

During the most susceptible part of the life-cycle of fish, *i.e.* the development of eggs and larvae, oil pollution can be critical. Abnormalities at various stages of embryonic developments have been observed in experiments using oil treated seawater. To study the interaction of oil on aquaculture further experimentation is required on the concentration, distribution and persistance of the aromatic and sulphur containing fractions. Large scale accidental spillages in the vicinity of aquaculture areas can have a devastating effect on organisms as demonstrated by the recent disaster of 'AMICO CADIZ' in March 1978. However, persistant sub-lethal oil pollution can have prolonged effect on the survival and growth of the cultivable organisms.

Thermal Pollution

Temperature of the ambient water, when altered from natural levels can be a lethal, or controlling or directive factor for fish (Fry, 1947). Below a specific temperature, with variations for species, activity becomes reduced to low levels. When temperature rises above the optimum activity dimnishes considerably and at high levels, death results (Sylvester, 1972).

In the marine environment thermal effluents may cause a local increase in salinity as well as temperature, thus affecting the distribution of organisms. Reproductive cycles may be disrupted by elevated temperatures and migration routes may be altered (Coutant, 1968). With increasing temperature, toxicities of some substances are increased and the resistance to disease lowered (Jones, 1964). In the presence of domestic and industrial wastes, a slight increase in temperature could cause fish mortalities through synergism. Synergism results when total effect of two or more substances is greater than the effect of each separately. Deviations from optimum temperature could also cause a cessation of spawning behaviour or an increase of abnormal fry.

Pesticides

The green revolution in its wake has necessitated the introduction of high yielding varieties of food crops which are comparatively more susceptible to the attack of pests. Hence in recent years large doses of pesticides have been used to augment agricultural production. Though banned in several countries, farmers in India have been using chlorinated hydrocarbons in place of biodegradable pesticides due to the cost-factor involved in procurement and application. This has resulted in considerable build up of DDT and such other pesticides in the waterways and sediments. DDT in commercial pesticide formulations for agriculture and other uses is somewhat impure and in addition to the major component, PP' DDT, it contains ortho para DDT and DDD. Although these compounds are very similar in structure, PP'DDT is virtually inactive and DDD is only moderately toxic to a range of restricted species. Although all these are extremely insoluble in seawater they can act by skin contact with particles which can be dissolved in skin lipids. It can also be ingested with food. So, in culture systems adjacent to paddy fields or connected to run-off from paddy field there is the likelihood of contamination from organochlorine compounds.

Most of the marine fishes are extremely susceptible to PP'DDT while crustaceans tend to accumulate the same in high concentration beneath the exo-skeleton. Besides, the biodegradation of PP'DDT even to 50% level takes a few years and complete elimination takes several decades. Two other common pesticides Dieldrin and Endrin have respectively 40 times and 100 times more toxicity than DDT. In recent years organophosphorus pesticides such as Malathion and Parathion and carbonate compounds are also increasingly used. Though these are also very toxic to fresh water fishes, the danger to the marine environment has been considered at present insignificant. Large scale development of aquaculture in the low lying areas adjacent to extensive paddy fields requires careful evaluation of the presence of pesticides in the ecosystem.

Conclusion

The national policy for marine fisheries development envisages a production of 2.8 million tonnes by 1983 and coastal aquaculture has been given top priority in the development programme in view of its great potential for augmenting production and providing employment opportunities as well as its role in integrated rural development.

It is not enough if production is increased through various inputs in aquaculture but stability of production must be enhanced and ensured. For this purpose it is imperative that factors such as aquatic pollution which diminish production and upset planning should be effectively controlled through various measures such as ;

1. Value judgement to set the level of acceptable and deleterious effects considering economic, political and social factors.
2. Strong national policy to ensure that potentially hazardous materials do not occur in one place and at one time in sufficient quantities to produce deleterious effects.
3. Water quality criteria and standards for inland, estuarine and coastal areas.
4. Proper effective programmes by Research and development organisations to control pollution and establish tolerance levels.
5. Recycling of wastes for cultivable organisms.

The approach to the protection of the marine environment with reference to aquaculture industry should be considered in totality taking environmental development as an integral programme. For this purpose a national pollution control and abatement programme is suggested on the following lines (Lesaca, 1977).

(*a*) Identification, surveys and monitoring of polluted areas.

(*b*) classification of rivers, waterways and other water bodies or watersheds in accordance with best usage or objective.

(*c*) measurement of parameters needed to establish aquatic pollution.

(*d*) periodic inspection and assessment of effects and impacts of pollution from all sources.

(*e*) industrial installation of pollution control equipment.

(*f*) research to identify local ecological conditions and establish tolerance levels of aquatic resources to pollution.

(*g*) review and revision of existing rules and regulations.

The Indian Standard Institution has set tolerance limits for industrial effluents discharged into marine coastal areas and for water quality after receiving discharges (ISI—7967 and 7968, 1976). In the latter the standards are same for bathing, recreation, shellfish and commercial fish culture and salt manufacture. Specifications have been indicated for colour and odour, floating material, suspended solids, oil and greasy substances and also for lethal chemicals such as arsenic, mercury as well as free ammonia, phenolic compounds etc. But at present there is no agency to enforce the criteria or standards. In this context, the recent findings on the chlorination of drinking water, points to the sad reality that certain chemicals which serve us well today hold many hidden dangers. Because of its great oxidising power, chlorine is highly reactive and combine in a variety of ways with both inorganic and organic compounds. Some such compounds are suspected as carcinogens and mutagens. Hence constant up-dating of criteria and standards and perpetual vigil are essential so that the oceans which have a finate capacity to assimilate man created wastes remain a safe environment for all the living resources they support.

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STUDIES ON THE BIOTIC CHARACTERISTICS IN AND AROUND THE OUTFALL AREAS OF PAPER MILLS AT TRIBENI, HAZINAGAR AND TITAGARH, WEST BENGAL

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ABSTRACT

Effluents from tissue paper mill at Tribeni and sulphite and sulphate process paper mill at Hazinagar and Titagarh near Calcutta contain large quantities of highly biodegradable and resistant type of organic and inorganic materials. Studies on the seasonal distribution of surface plankton in and around the outfall areas of these paper mills indicated lowest plankton biomass at the direct outfall area, while it did not show any appreciable correlation with the effluents around the outfall. Differential dilution of the effluents was found to affect the distribution pattern of the plankton in the area, although it showed the normal winter and premonsoon peaks.

The distribution of benthic biota was poor particularly in the vicinity of the outfall and was almost absent at the direct outfal indicating harmful nature of the accumulated wastes. Experiments on culture of plankton with soil base collected from different centres around the outfall showed regeneration and growth of plankton within two months. This growth phase continued upto five months. 100% survival of gastropods in cage experiments was recorded in the unpolluted and recovery zones while the mortality rate varied from 60 to 100% at the outfall area in different seasons. There is high accumulation of heavy metals in the soil in outfall and recovery region at Tribeni.

INTRODUCTION

THE HOOGHLY RIVER basin is a very important problem area where the population has almost crossed the saturation limit in certain sectors. A large number of industrial establishments are located along this estuary. The disposal of untreated or partly treated industrial effluents and domestic wastes in this highly industrialised belt of the estuary and its impact on the aquatic life has been under study for quite some time by a few workers only. Basu *et al.* (1970) ; Ghosh *et al.* (1976) ; Ghosh *et al.* (1977) ; Ray *et al.* (1977) ; Gopalakrishnan *et al.* (1973).

The present communication deals with the information collected from studies around the outfall areas of three paper mills viz. Tribeni Tissue mill (soda process), Indian Paper & Pulp industries (sulphite process) and Titagarh Paper Mills (sulphate process) situated respectively at Tribeni about 60 km north west of Calcutta, at Hazinagar about 50 km north east of Calcutta and at Titagarh about 35 km north east of Calcutta (Fig. 1). The effluents from these paper mills contain large quantities of highly biodegradable and resistant types of organic and inorganic materials. The purpose of this study was mainly to ascertain the likely harmful effects of these effluents on the aquatic biomass *viz.* surface plankton and bottom benthos of this stretch of the Hooghly estuary.

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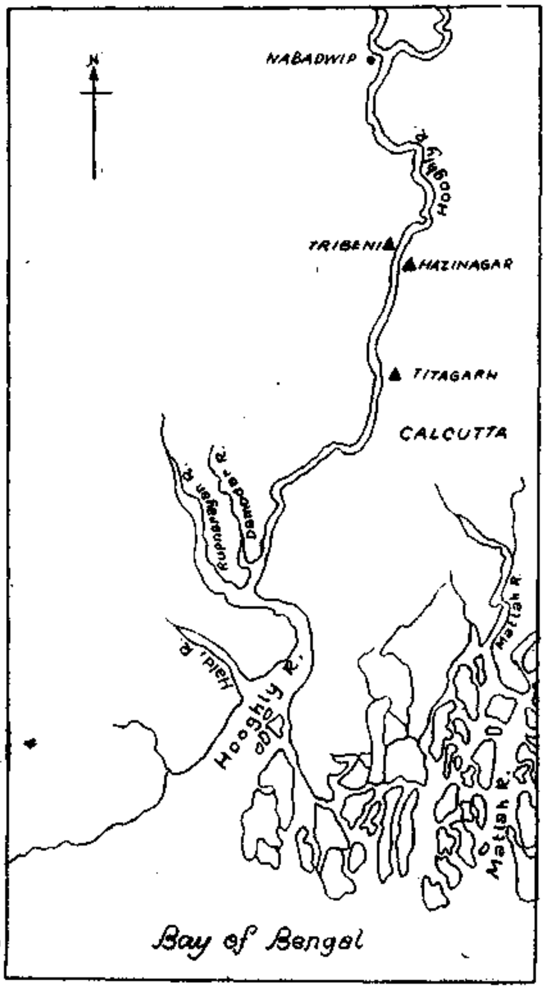

Fig. 1. The Hooghly-Matlah Estuarine system with sampling stations.

Hydrological Characteristics of the Estuary

The Hooghly estuary is a funnel shaped estuary and is always subjected to the tidal influx and riverine discharges. The dilution pattern becomes complicated by the tidal actions (four tidal regimes in 24 hours) which oscillates a portion of the pollutant back and forth in the stretch and thus influences the retention period of the pollutants. Alexander *et al.* (1935) also supported this observation in their paper on ' Survey of the river Tees ' and also reported that the conclusion may be drawn that polluting matters cannot escape seawards easily unless it is in the surface layer. This is of importance in considering the discharge of effluents due to the presence of lighter surface fresh water and denser salt water wedge at the bottom of the estuary. Specific indicator organisms for pollution were not detected in this stretch due to the strong and oscillating tidal intermixing.

During summer, particularly under neap tidal conditions, the flood tide influence is felt only in the marginal areas. The mid-stream stretches of the estuary undergo apprecia ıle dilution with the fresh water inrush and hence are subjected to minimal pollutional stress during monsoon. The ebb tidal flow lasts for a longer time than the flood tidal flow and generally the duration of ebb tidal flow is 6.5-8.5 hrs. in the dry season and 7.0-11.5 hrs. in the monsoon months, while that of flood tidal flow is 4.0-6.0 hrs. and 2.5-4.0 hrs. in the dry season and monsoon respectively. The details have been described elsewhere by Gopalakrishnan *et al.* (1973).

Material and Methods

Four sampling centres were established around the main outfall area of each paper mill viz. 1st 200 mts above the outfall, 2nd at the outfall, 3rd 200 mts below the outfall and 4th 400 mts below the outfall. Samples were collected fortnightly at low tide level for surface plankton, benthos, bottom soil and water for plankton regeneration and heavy metals estimation. Cage experiments were conducted with gastropods as test animals to determine survival rate, 20 animals were kept in each cage at soil water interface for 48 hrs. and the cages were moved depending on the tidal flow (only at Triveni). Collection and techniques followed for surface plankton was the same as described by Shetty *et al.* (1961) and benthos was collected by Ekman dredge (16^2 cm) and strained through a 0.5 mm seive and preserved in 10% formalin. For plankton regeneration studies bottom soil was collected from different centres and was kept in glass jars with river water. Occurrence of heavy metals was estimated by atomic absorption spectrophotometer analysis.

Observations and Discussion

Phytoplankton — The results of the investigations conducted since the inception of this programme have indicated that phytoplankton plays the dominant roll in determining the quantitative distribution of total plankton in the Hooghly-Matlah estuarine system and diatoms mainly determine the seasonal and spatial distribution of phytoplankton (Shetty *et al.*, 1961 and Saha *et al.*, 1975). The present observation also confirms this trend. The other significant points indicated low phytoplankton biomass at the direct outfall areas, while it did not show much appreciable correlation with the dispersal of effluents around the outfalls (Fig. 2 to 4). Differential dilution of the effluents was found to be responsible for distribution pattern of the plankton in the area although it also showed the normal winter and pre-monsoon peaks as reported earlier. The important phytoplankters responsible for the abundance in the different centres are as below:

Diatoms

Concinodiscus granii, *Coscinodiscus* sp., *Melosira granulata*, *Synedra ulna* and *Nitzschia* sp. etc. Bluegreen algae — *Oscillatoria* spp., *Microcystes* sp. and *Anabaena* sp. Greenalgae—*Spirogyra* spp., *Pediastrum* sp., *Scene-*

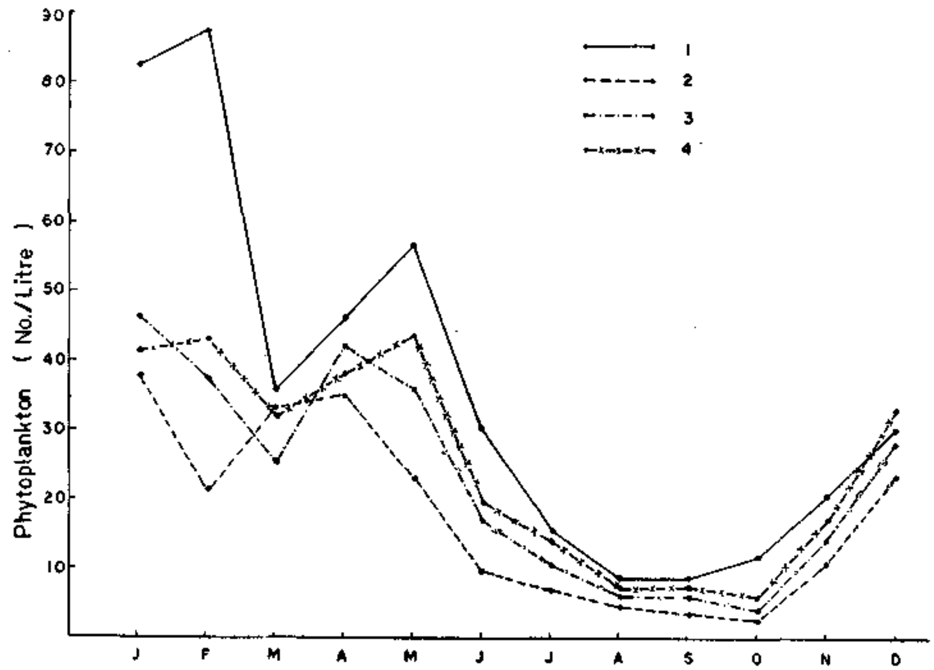

Fig. 2. The average monthly phytoplankton (No./litre) at four centres around the outfall of Tribeni Tissue Mill.

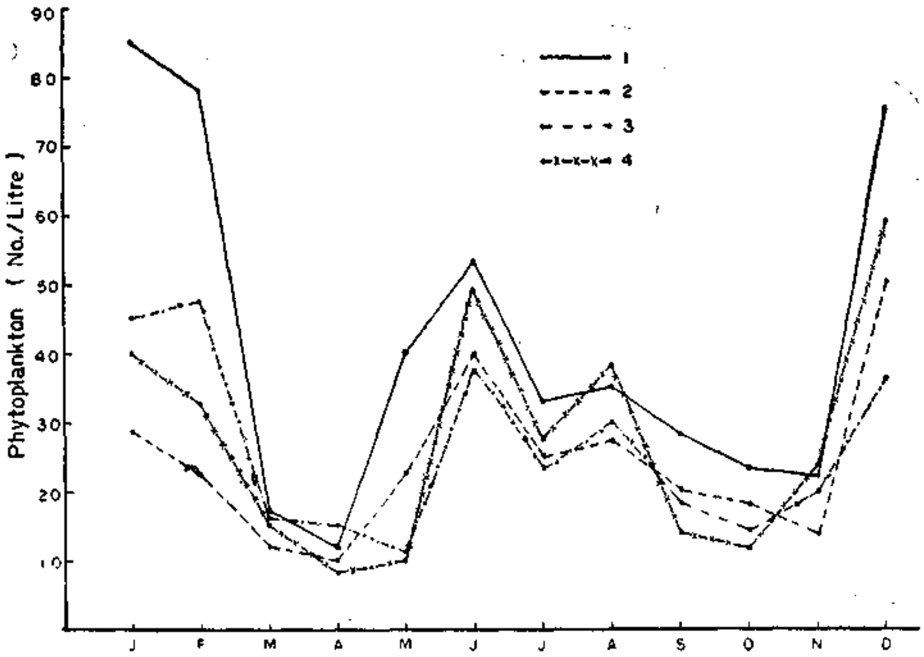

Fig. 3. The average monthly phytoplankton (No./litre) at four centres around the outfall of Hazinagar Paper Mill.

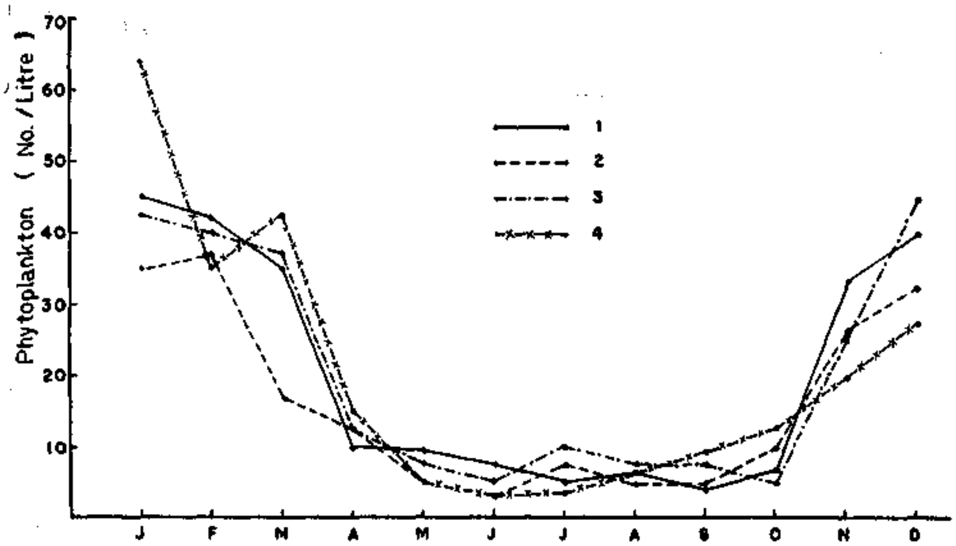

Fig. 4. The average monthly phytoplankton (No./litre) at four centres around the outfall of Titagarh Paper Mill.

desmus sp., *Endorina* sp., *Volvore* sp. and *Borjia plenktonica* etc.

Zooplankton

The monthly centrewise averages of zooplankton distribution are shown in Fig. 5 to 7. The present data as well as those published earlier, show that the zooplankton also show two peaks of abundance every year, during the winter season (Nov.-Jan.) and premonsoon season (June-Aug.). Like phytoplankton, 200 plankton also show comparatively lower distribution at the outfall area indicating the harmful effect of the effluents specially at the outfall area. Higher numbers encountered at the centres above and below the outfall area indicates again slight recovery from that effect.

almost absent at the outfall areas due to accumulation of highly decomposing organic and other harmful inorganic materials. The dominant forms encountered were gastropods—*Viviparus* sp., *Lymnaea* sp. and *Melanoides* sp., Olegochaetes (tubifecid worm)—*Tubifex tubifex* and a few megalopa and other fish larvae. Range of occurrence was 0-15 nos. per haul.

Regeneration of plankton

Experiments conducted in the culture of plankton in unpolluted water with soil base collected from different centres around the outfall of the Triveni tissue mill showed that regeneration and growth of plankton takes place within two months. The maximum

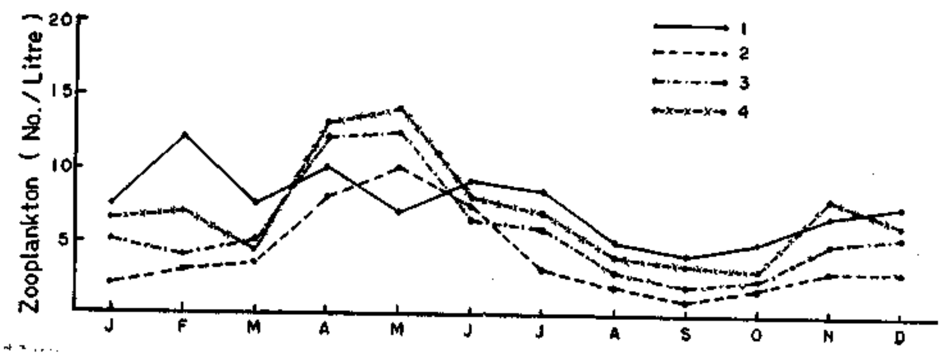

Fig. 5. The average monthly zooplankton (No./litre) at four centres around the outfall of Tribeni Tissue Mill.

The most dominant zooplanktonic forms observed are *Cyclops* sp., *Diatomus* sp., *Pseudodiaptomus* sp. among copepods ; *Maina* sp., *Bosmina* sp. and *Ceriodaphnia* sp. among cladocera, some protozoan forms like *Vorticella* sp. *Difflugia* sp. and *Aveella* sp. ; larval forms mostly of invertibrate—gastropod and lamellibranch veligers, crustaceans such as nauplii, megalopa and mysis.

The occurrence of benthic organisms was poor all along the area due to sifting of fine silty bottom and tidal scouring action and was

growth rate was recorded in the 3rd and 5th months respectively in the case of soils from unpolluted and outfall areas. Maximum number observed in unpolluted soil was 30/lit. and in outfall area soil was 65/lit. Number of species encountered at the outfall was less but the density was appreciably higher indicating richness of organic matter in the bottom soil of that area. Initial growth of plankton was slow but developed higher concentration after 3-4 months indicating that it may take 3-4 months time for this aquatic ecosystem to attain equilibrium.

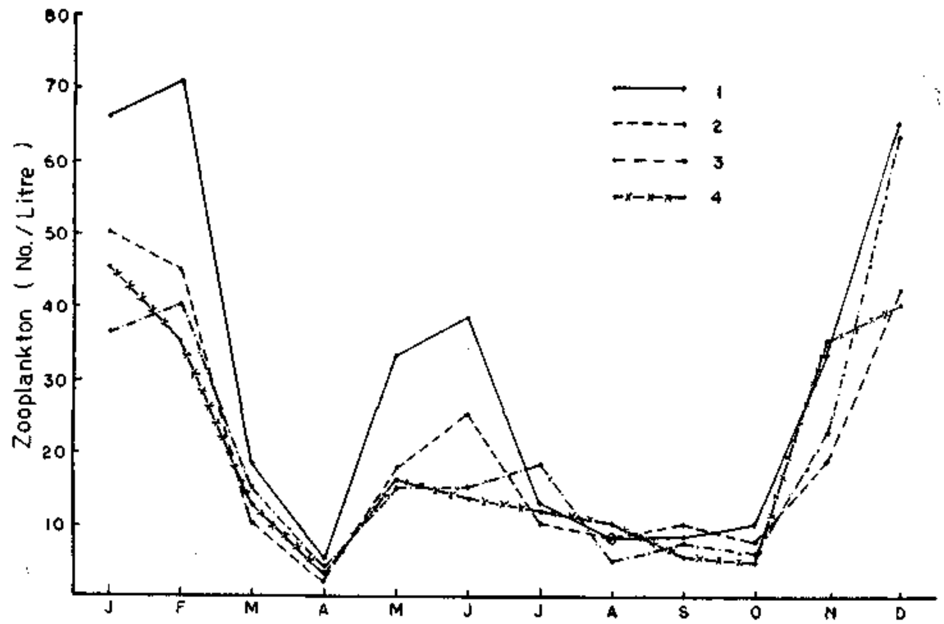

Fig. 6. The average monthly zooplankton (No./litre) at four centres around the outfall of Hazinagar Paper Mill.

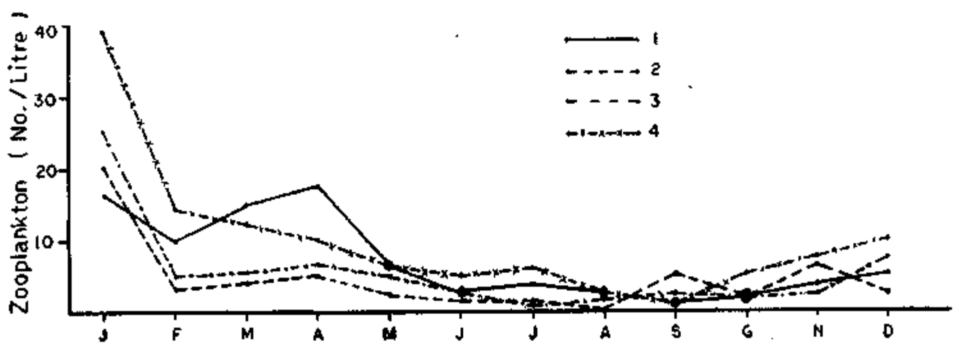

Fig. 7. The average monthly zooplankton (No./litre) at four centres around the outfall of Titagarh Paper Mill.

After the 5th month plankton population showed gradual decrease in number. Best results were obtained in the experiments carried out with the soil base collected during monsoon followed by that of collected in winter months. The main phytoplanktonic forms observed in these cultures were *Oscillatoria* sp., *Spirogyra* sp., *Ankistrodesnum* sp., *Synedra ulna*, *Navicula* sp.

and *Cymbella* sp. etc. and zooplanktonic forms were protozoan Ciliates, Euglenoids and Rotifera etc.

Cage culture experiments

To determine the survival rate of aquatic organisms in the outfall area, experiments were conducted with gastropods (*Lymnaea* sp.) as test animals. They were kept at soil water interface for 48 hours. 20 animals were kept in each cage and the cages were moved depending on tidal flow. The results of the observations are given in Table 1.

TABLE 1. *Number of gastropods* Lymnaea *sp. dead when kept in cages* (20 *animals/cage*) *at selected* 4 *centres at Tribeni tissue mills during different seasons*

	Seasons (1)	Seasons (2)	Centres (3)	Centres (4)
Summer				
11-5-78, 12-5-78	Nil	8	10	Nil
12-5-78, 13-5-78	Nil	12	10	Nil
Monsoon				
24-8-78, 25-8-78	Nil	4	3	Nil
25-8-78, 26-8-78	Nil	6	5	Nil
Winter				
11-1-79, 12-1-79	Nil	8	5	Nil
12-1-79, 13-1-79	Nil	12	10	Nil

These results clearly indicate the harmful nature of the bottom soil towards benthic biotic life along the 400 mts stretch around the outfall of this paper mill. Occurrence of heavy metals like iron, copper, zinc and manganese in the water and specially in the bottom soil around the outfall area of Triveni tissue mills was also estimated to study their harmful effect on the aquatic biomass. The analysis was done with the help of an atomic absorption spectro-photometer and the results are given in Table 2. The unusually high concentration of zinc and iron at the centre no. 1 is due to the discharge of a rayon mill some 200 mts. above (Ghosh *et al.*, 1976).

TABLE 2. *The concentration of heavy metals in soil and water at different centres at Tribeni tissue mills*

Centres		Heavy metals in ppm Fe.	Cu.	Mn.	Zn.
1. Unpolluted	Soil	43	0.8	23	0.9
2. Polluted	Soil	25	1.2	28	0.8
4. Recovery	Soil	20	1.1	18	0.7
2. Polluted	—water	80	3.5	35	1.1

Doudoroff (1952) found that although fish could survive for 8 hours at 8 mg/lit. of zinc alone and 0.2 mg/lit. of copper alone, most fish died within 8 hours when exposed to a mixed solution containing only 1.0 mg/lit. of zinc and 0.025 mg of coppr. The water pollution control board of England conducted similar experiments with rainbow trout in both soft and hard waters. The results showed synergism at this higher concentration in soft water, although the threshold concentration for the mixed copper and zinc are about the same that would be expected on an assumption that there was no synergism. In hard water no synergism between cu and zn are evident.

Cu concentration as low as 0.1 to 0.5 mg/lit. have been reported toxic to bacteria and other micro-organisms. The heavy metals observed at Triveni show much higher concentration which might have affected the aquatic biomass. Moreover, due to bioaccumulation of heavy metals, fish flesh is likely to contain some metalic ions which will be transmitted inadvertantly to the consumers causing health hazards.

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THERMAL POLLUTION OF COASTAL WATERS AND ITS EFFECT ON FISH SURVIVAL

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ABSTRACT

Thermal discharges from the ever increasing power plants are bound to pollute our waters to affect the survival, growth, reproduction and behaviour of fishes and shellfishes. Intake water for cooling can be heated 5-10°C higher than the ambient condition at the release point and the immediate effect expected is lethality to aquatic animals, especially in summer when ambient temperature in tropics would be high and close to the lethal point. While fish might survive at a lower temperature the sharpness of the lethal temperature is such that even the slightest change can cause mortality. While temperature kills directly, its sublethal effects are as serious in causing production changes. The sublethal effects can be abrupt changes in behaviour, such as preference or avoidance of the polluted area, or can be long term changes in relation to metabolism, growth and reproduction.

Thermal relations of 3 euryhaline fishes, namely the milkfish (*Chanos chanos*), *Tilapia mossambica* and the mullet, *Rhinomugil corsula* have been investigated. *R. corsula* is stenothermal, having a tolerance area (569°C^2) as compared with goldfish (1220°C^2) and mrigal, rohu, fringe-lipped carp and common carp (862, 850, 731 and 1075°C^2) respectively. The upper thermal tolerance of the fishes acclimated to 30°C are compared. The median lethal time (LT_{50}), at which the 50% of fish tested die, has been estimated by plotting the cumulative per cent death against time of death for each test temperature in a probability chart. The LT_{50} values for the milkfish are 38, 52, 980, 1450 and 4700 minutes, when tested at 42.5, 42.0, 41.5, 41.0, 40.5°C respectively. In the case of *Tilapia* the LT_{50} values are 16, 47, 162, 2780 minutes, when tested at 42.0, 41.5, 41.0, 40.0°C respectively. In *R. corsula* the LT_{50} values are 39, 64, 103, 320, 650, 1550, 2000 minutes, when tested at 41.0, 40.5, 40.0, 39.5, 39.0, 38.5, 38.0°C respectively. While milkfish can survive indefinitely at 40°C (acclimation 30°C) all *Tilapia* and mullet exposed, died within 3770 and 171 minutes respectively and while milkfish survives for 150 minutes at 42°C, all the other fishes tested face instantaneous death. The incipient lethal temperatures (temperature at which 50% of the fish can survive indefinitely) of fishes acclimated to 30°C were estimated to be 40.3, 39.5, 36.2 for milkfish, *Tilapia* and freshwater mullet. Thus a comparison of upper temperature tolerance of the three species studied indicates that the milkfish has higher tolerance than *R. corsula* and *T. mossambica* and also carps studied.

One of the sublethal effects studied for *R. corsula* and *Tilapia* only is the inhibition of swimming at the temperature extremes. The upper lethal temperatures for swimming inhibition of fish swimming in water currents of 38, 62, 72 cm/sec, which is of relevance to pollution by thermal effluents, have been estimated as 39.7, 38.4, 37.0°C in the case of *Tilapia* and 35.2, 34.6, 34.2°C in the case of mullet. Inhibition of swimming or activity as a behavioural index is important as the ability of the fishes for foraging and escape from predation will be dependent on sustained activity. Mullets, milkfish and *Tilapia* are common in the brackishwater areas such as the one now endangered by the thermal plant at Tuticorin and further studies are called for to determine the biological impact of similar industries.

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INTRODUCTION

WITH the ever increasing need for power, thermal power generation units are bound to be on the increase. To take the example of power development in Tamil Nadu alone the installed capacity increased from 256 MW in 1951 to 2719 MW in 1979. While thermal power generation has become a necessity and also is of great advantage (per capita power consumption has increased from 12 units in 1951 to 175 units in 1978-79 in Tamil Nadu) it also has to be pointed out that the thermal units need vast amounts of water for cooling. This cooling water has to be pumped from natural systems, rivers, lakes or sea and discharged back into the same environment thereby increasing the environmental temperature considerably. If the water temperature is to be increased by 5-10°C, what effects would this cause to the aquatic fauna and flora, especially those on which we depend for our food and commerce? This is the basic problem in thermal pollution faced by the environmental biologist and the fishery scientist. Besides the thermal pollution, the thermal plants using fossil fuels have as byproduct flyash which is also let into the environment if not recycled. A further mechanical aspect of these power units are that, while sucking in and discharging a huge quantity of water several organisms are entrained along with the water causing damage to them. In the present study we shall be looking at specifically the therml effects caused by thermal discharges from the power plants.

It is often presumed that the tropical environment with naturally high temperature would not be seriously affected by the thermal effluents. This assumption is erroneous, for the ambient temperatures of natural waters in the tropics are very high, often very close to the upper lethal limit, especially during the summer months. The tropical organisms, like the homeotherms, not only live near the upper tolerance limit but also perform efficiently at these temperatures. What is often not realized is that any slight increase in temperature such as that caused by the thermal discharges often pushes the organisms over the tolerance limit and causes mortality and irrepairable damage to the ecosystem. This can be judged only by careful pre-release and post-release ecological surveys of the discharge area (Merriman, 1965; Leggett, 1971).

While the lethal response is recognized as the most important of the critical thermal responses the sublethal responses are no less significant. Survival and occurrence of an organism in a particular site would much depend on the type of sub-lethal response as well. The immediate responses of an organism to raised temperatures are shock reactions, resulting often in death, avoidance and preference responses. The latter two behavioural responses are significant, for these would explain the occurrence of motile organisms in a particular site. The long-term thermal responses are those which affect the physiology and metabolism and thereby growth and reproduction of the organisms. Both the short-term and long-term responses are important as these two together decide the survival of the species. Interaction of temperature with other physical and chemical factors in the environment are equally important in deciding the survival of organisms. Thus the thermal discharges often loaded with biocides used in cooling waters along with the flyash often accumulating in the vicinity deserve to be studied seriously in protection of our aquatic environment.

THERMAL RELATIONS OF AQUATIC ORGANISMS

Biological relations of temperature are of basic interest to the study of thermal pollution and therefore these aspects are discussed in some detail hereunder. Temperature is often referred to as the master factor in the environment. Temperature acts as a lethal factor at both extremes, destroying the integrity of the organisms, as a controlling factor regulating metabolism and thereby activity and growth, and as a directive factor, regulating behaviour (Fry, 1947 ; 1971 ; Kutty *et al.*, 1978). While the lethal factor effects survival directly, the latter causes sublethal or pre-lethal effects on the organisms.

Lethal Effects of Temperature

Lethal effects of temperature on certain local fishes were studied for comparing the relative tolerance to raised temperatures as those existing in the thermal discharge areas. Two separate series of experiments were made, one exposing a lot of fishes and crustaceans to a graded increase in temperature, and the other exposing three species of teleosts acclimated to specific conditions, to single fixed high temperatures separately.

We have also attempted to study the sublethal responses of two euryhaline fishes namely *Rhinomugil corsula* and *Tilapia mossambica*. Observations have been made on critical temperatures which cause swimming inhibition (rheotactic avoidance temperature) and also on thermal avoidance of *Tilapia* in quiet water (non-rheotactic avoidance). These observations are discussed hereunder.

Thermal tolerance and resistance of Rhinomugil corsula

The lethal effects of temperature involve two separate capacities of the organism namely thermal tolerance and thermal resistance. The thermal tolerance of an organism can be estimated by acclimating groups to various temperatures within the biokinetic range and exposing them to specific high and low temperatures where the organisms begin dying. Then a plot can be made of temperatures, both high and low, at which 50% of the exposed lot die, against respective acclimation temperatures. The plot will describe a polygon bounded by the two axes and lines drawn through the experimentally determined upper and lower temperatures and a vertical line drawn through the plot of the highest temperature at which the organism can survive (ultimate upper incipient lethal temperature ; Fry, 1947). This point can be obtained by extrapolating the line drawn through the plots of upper lethal temperatures to a line drawn at 45° to the axes. A thermal polygon, so obtained for the freshwater mullet, *Rhinomugil corsula* is shown in Fig. 1. The area bounded by the polygon describes the thermal tolerance of the fish.

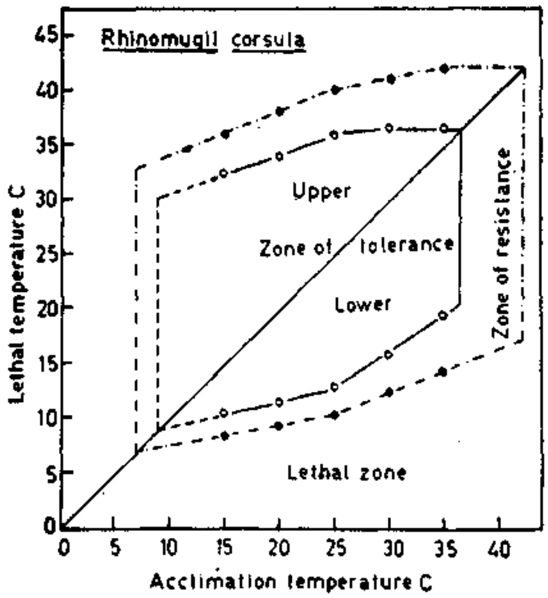

Fig. 1. Zones of thermal tolerance and resistance of *Rhinomugil corsula* in freshwater.

R. corsula is stenothermal having a tolerance area of 569°C² as compared with goldfish (1220°C) (Fry *et al.*, 1942) and mrigal, rohu, fringe-lipped carp and common carp (862, 850, 1731 and 1075°C²) (Kasim, 1978) respectively. However the mullet has a larger tolerance area than the air-breathing fish, *Channa punctatus* (410°C²) (Ananthakrishnan and Kutty, 1976).

Thermal resistance can also be so quantified from the area outside the thermal tolerance zone, also indicated in Fig. 1. The length of time for which an organism can survive in a lethal temperature, referred to as resistance time, need not be proportional to tolerance capacity. Often the two are inversely related (Fry, 1971 ; Kasim, 1978 ; Kutty *et al.*, 1978).

Survival of fishes and crustaceans of Tuticorin Bay to graded increase in temperature

To study the temperature tolerance of fishes and crustaceans of the bay, where the heated water from the thermal power plant is to be discharged, a collection of 6 species of fishes, *Gobius optomus* (0.1—0.22 g), *Mugil* sp. (0.15—0.21 g) *Scatophagus argus* (0.07—0.22 g), *Therapon jarbua* (0.29—0.41 g), *Tetradon leopardus* (0.22—0.42 g) and *Syngnathus carce* (0.09—0.31 g) and two crustaceans, *Penaeus indicus* (0.23—0.75 g), and *Squilla* sp. (0.22—1.40 g), was made. They were maintained in the laboratory under natural conditions of temperature and salinity at the time of capture (28°C and 6 pp t S) overnight prior to exposure to higher temperatures at 6 ppt salinity. They were subjected to graded increase (0.5°C/15 min) in temperature so as to simulate exposure in a thermal gradient as that could exist in a thermal discharge area. Data on temperatures to death of individual fish exposed to this graded increase of temperature were obtained for all the 8 species of fishes and crustaceans and plotted in an arithmetic grid against the percentage of death (Fig. 2). The upper median lethal temperatures (LD_{50}) for the 8 species obtained from the eye-fitted curves (Fig. 2) and geometric means are given in the Table 1. It is evident that the thermal tolerance of the 8 species tested are in the order of *Squilla* sp. < *Gobius optomus* < *Tetradon leopardus* < *Penaeus indicus* < *Syngnathus carce* < *Scatophagus argus* < *Mugil* sp. < *Therapon jarbua*. Among the species tested *Therapon jarbua* is the most tolerant and *Squilla* the least.

TABLE 1. *Median lethal temperatures (LT_{50}) of 8 species of fishes and crustaceans from Tuticorin Bay exposed to a graded increase of temperature at the rate of 0.5°C/15 min.*

Species		Median lethal temperature (°C)	
		From eye-fitted curve	Geometric mean
Squilla sp.	..	38.0	38.38
Gobius optomus	..	40.6	40.43
Tetradon leopardus	..	40.7	40.35
Penaeus indicus	..	41.7	41.50
Syngnathus carce	..	42.0	41.39
Scatophagus argus	..	42.3	41.89
Mugil sp.	..	42.7	42.72
Therapon jarbua	..	43.5	43.22

Survival of Rhinomughil corsula, Tilapia mossambica *and* Chanos chanos *exposed to high temperature*

The upper thermal tolerance of 3 euryhaline teleosts acclimated to a single temperature and exposed to fixed high thermal temperatures separately until death occurred, is compared. Data on times to death of individual fish (milkfish (2.1—2.8 g) and *Tilapia* (2.6—2.8 g) acclimated to 30°C and exposed to various high lethal temperatures from 40.5 to 42.5°C were obtained. The median lethal times LT_{50} for the two species tested have been obtained by plotting the cumulative per cent death against time of death for each test temperature in a probability chart and graphically illustrated in a semi-logarithmic grid against test temperatures along with the data for *R. corsula* acclimated to 30°C in Fig. 3. LT_{50} values for milkfish are 38, 52, 980, 1450 and 4700 minutes when tested at 42.5, 42.0, 41.5, 41.0 40.5°C respectively. In the case of Tilapia the LT_{50} values are 16, 47, 162,2780 minutes when tested at 42.0, 41.5, 41.0, 40.0°C respectively. Complete thermal tolerance and resistance of *R. Corsula* worked out in our laboratory have been referred to earlier hereunder. The LT_{50} values of this species are also furnished in Fig. 3. The values are 39, 64, 103, 320, 650,

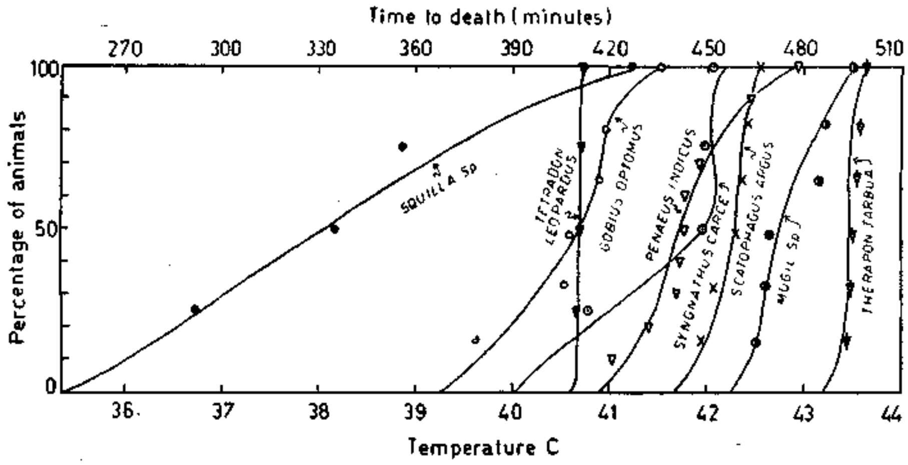

Fig. 2. Lethal temperature of 8 species of fishes and crustaceans from Tuticorin Bay. Lots of 4-10 numbers of each species were exposed to graded increase in temperature (0.5°C/15 min) from holding temperature of 28°C. Each point indicates the time and temperature of death of each animal.

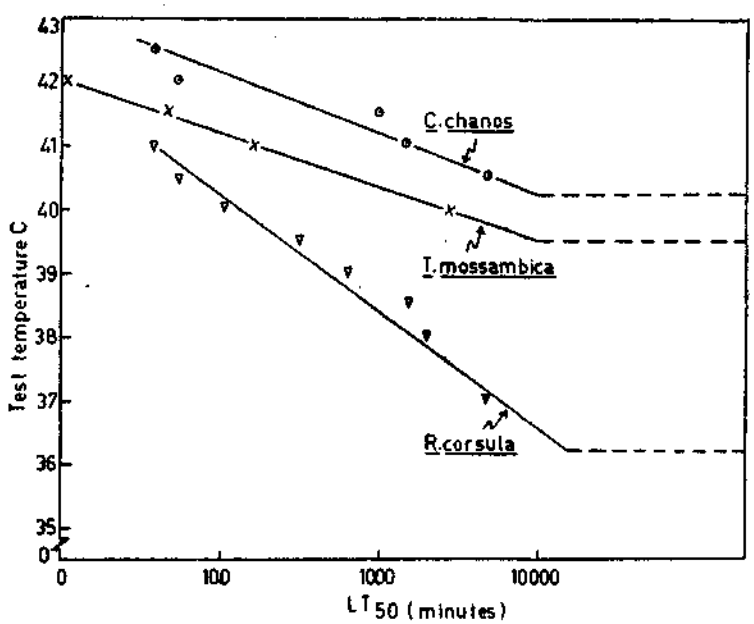

Fig. 3. Mediani ethal time (LT_{50}) to high temperatures among *R. corsula*, *T. mossambica* and *C. chanos* acclimated to 30°C and exposed separately to various fixed high temperatures. The flexion of the curves indicate incipient lethal temperature, point separating the tolerance and resistance zone. Plotted on arithmetic-logarithmic axes.

1550, 2000 minutes for *R. corsula* acclimated to 30°C and exposed to 41.0, 40.5, 40.0, 39.5, 39.0, 38.5, 38.0°C respectively. While milkfish can survive indefinitely at 40°C all Tilapia and mullet exposed died within 3770 and 171 minutes respectively and while milkfish survive for 150 minutes at 42°C, all the other species tested face instantaneous death.

The upper incipient lethal temperatures for milkfish and Tilapia acclimated to 30°C are also estimated as per the method outlined by Miller and Tainter (1944). The values are 40.3 and 39.5 for milkfish and Tilapia respectively, as compared with that of *R. corsula* (36.2°C). Thus it is evident that among the three euryhaline fishes studied the milkfish has higher tolerance than *T. mossambica* and *R. corsula*.

Sublethal Effects of Temperature

The thermal inhibition of swimming in R. corsula *and* T. mossambica

As pointed out by Fry (1971) these should be rightly referred to as pre-lethal effects. These are listed in Table 2 according to the severity of the response. We have attempted to judge the severity taking the level of temperature as a criterion but the responses are complex and difficult to be so analysed. It is however felt that the classification would be useful in understanding thermal responses.

The sublethal effects can be either short-term shock responses or long-term effects. Among the short-term responses the behaviour responses, especially those with reference to avoidance and preference reactions are most important. Avoidance of temperature can again be different depending on the ambient water conditions whether, it is quiet (stagnant) or running water. It has been shown that the avoidance temperature in the running water is slightly higher than that in quiet water. Possibly there is a reinforcing effect of water currents which leads to a higher avoidance temperature. Thus in fish swimming in running water, the temperature of swimming inhibition measured has been taken as the avoidance temperature of the fish for the specific water current speed. We have examined this in the case of both *Rhinomugil corsula* and *Tilapia mossambica* (Kutty and Sukumaran, 1975). We have suggested that the temperature of swimming inhibition

Table 2. *A classification of responses of fishes exposed to thermal extremes*

Response Types	Remarks
I. Lethal	
A. Resistance B. Tolerance (Thermal death limit)	Temperature as lethal factor *per se* destroys the integrity of the organism resulting in mortality directly.
II. Sublethal	
A. Behavioural responses (i) Avoidance and preference reactions (*a*) Avoidance in running water (rheotactic avoidance) (*b*) Avoidance in quiet water (non-rheotactic avoidance) (*c*) Feeding behaviour (*d*) Reproductive behaviour	Temperature as a directive factor acting through central nervous system, affecting distribution and survival. Growth and species survival also affected by feeding and reproductive behaviour changes.
B. Physiological Responses: (i) Metabolic and growth effects (ii) Reproductive physiology (iii) Other physiological aspects	Temperature as controlling factor—total over the bioknetic range—suboptimal responses at thermal extremes.

can be taken as due to 'rheotactic' avoidance as opposed to 'nonrheotactic' avoidance in quiet water. Temperature also causes preference reactions, acting as a directive factor, which has been discussed by Fry (1947). Temperature also affects feeding and reproductive behaviour in the organisms again due to the thermal influence acting through the central nervous system.

Temperature acts as a controlling factor over the total biokinetic range of the species regulating almost all the physiological functions influencing total metabolism and growth. Temperature will also affect reproductive physiology similarly, restricting fecundity and even arresting reproduction. Measures of this type of thermal responses are meagre because of the long-term nature of the responses.

One of the sublethal effects of temperature studied in *R. corsula* and *T. mossambica* is the inhibition of swimming at the temperature extremes. The fish was forced to swim in a tunnel apparatus (Blazka *et al.*, 1960) described by Sukumaran and Kutty (1977). The pattern of swimming inhibition encountered while the temperature was increased or decreased to the tolerance extremes has been described by Kutty and Sukumaran (1975). As the critical temperature was reached the fish fell back in the tunnel ('reverses') but as soon as the thermal stress was released by bringing the ambient temperatures back towards the acclimation level, the fish swam steadily again. These critical upper avoidance temperatures at various swimming speeds (38, 62 and 72 cm/sec) for the both species acclimated to 30°C have been estimated as 39.7, 38.4 and 37.0°C in the case of Tilapia and 35.2, 34.6, 34.2°C in the case of mullet. The upper and lower critical temperatures of swimming inhibition of mullet and Tilapia are plotted against swimming speeds (Fig. 4). It is evident that the mullet has a very narrow zone of activity, when compared with that of *T. mossambica* agreeing with the stenothermal nature of mullet as already referred to. Kutty and Sukumaran (1975) and Kutty *et al.* (1978) have suggested that the critical temperatures of swimming inhibition can be taken as points in a thermal gradient as that expected in a current of water into which heated effluents are discharged.

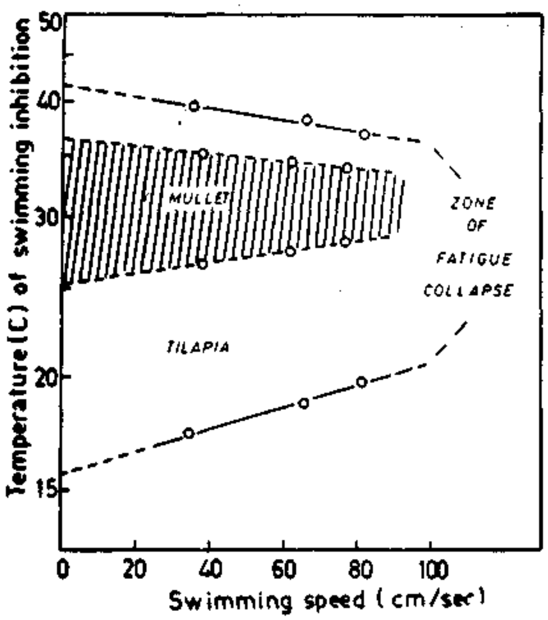

Fig. 4. Relation of temperature to swimming activity of *T. mossambica* and *R. corsula* acclimated to 30°C. Curves bounding the zones of activity are drawn through upper and lower critical temperatures of swimming inhibition.

It can be explained that fishes in such a current of water would distribute themselves avoiding temperatures above critical temepratures of swimming inhibition. A model showing curves connecting the points of critical temperatures of swimming inhibition for mullet and Tilapia for specific water current speeds and ambient temperatures are shown in Fig. 5. In the figure shown it is assumed that ambient temperatures changes of at a rate of 1°C/10 m from the source of the heated effluent, starting with an initial temperature of 41°C. From the figure it can be made out that *R. corsula* will be restricted to a much lower temperature than

T. mossambica in a current of water with a thermal gradient. For example in the model shown in Fig. 5, *R. corsula* would fail to swim at 35°C and avoid higher temperatures while *T. mossambica* will do so only at 39°C, when they are in a current of water at a velocity of 50 cm/sec. It can further be extrapolated that at a gradient of 1°C 10 m, the upper thermal margin of their distribution can be about 40 m, apart according to the assumptions made. It is realized that the model suggested is yet to be tested on several aspects.

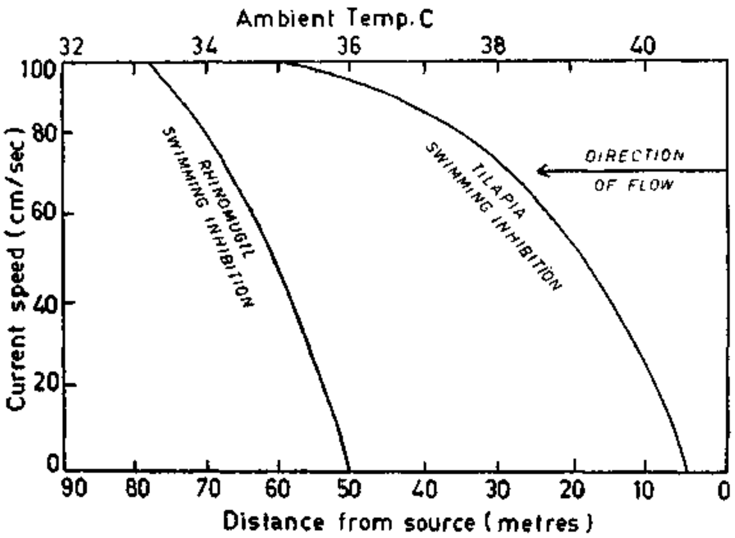

Fig. 5. Comparison of the thermal inhibition curves of *T. mossambica* and *R. corsula* acclimated to 30°C. The lines are drawn through critical temperature for various swimming speeds, which are taken as points in a thermal gradient in running water at which the fish fails to swim at a relative swimming velocity.

Understanding of thermal inhibition of swimming and fish distribution in water currents by the mechanism of rheotactic avoidance will be useful in studies on the effect of heated effluents of thermal power plants and changing environment.

Thermal avoidance of T. mossambica *in stagnant water*

Another aspect of sub-lethal effects of the temperature studied for *T. mossambica* is the upper avoidance of temperature in quiet water. The test fish was left in the avoidance trough and subsequent to an equilibration time of 5 minutes the time the fish spent in the control (acclimation) temperature (30°C) and test water (32°C) was noted for the next 10 minutes. The temperature of test water was subsequently raised by 1°C every 10 minutes and times the fish spent in each section of the avoidance chamber were noted as before. The results of this series are shown in Fig. 6. In the figure a score of 50% or above suggests that the fish was showing some avoidance and score of 100% would indicate complete avoidance (Sprague, 1964 ; Lipton, 1975).

Within the limited temperature range studied, it is seen that *T. mossambica* acclimated to 30°C, 50% avoidance took place at 32°C and avoidance was almost complete at 35°C and above.

It is seen that the upper critical temperatures of swimming failure in *T. mossambica* are much higher than its avoidance temperatures in relatively quiet water. As suggested earlier a positive rheotactic response might induce fish to enter heated running water, which would otherwise be avoided. Thus it would appear

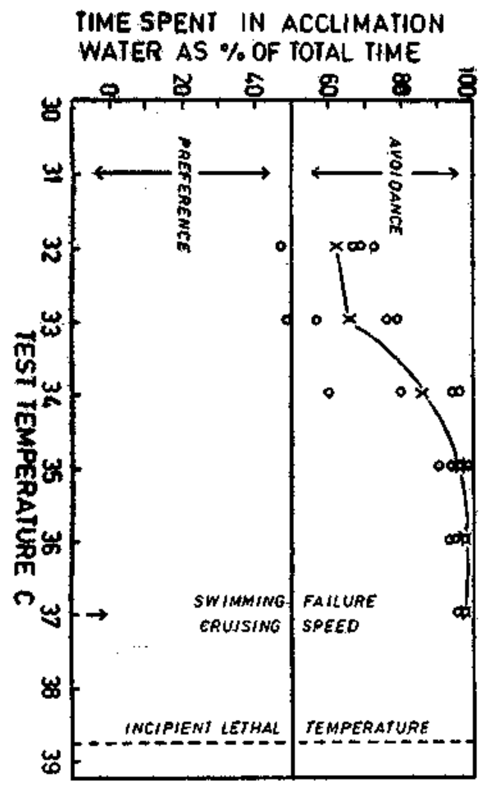

Fig. 6. Avoidance response of *T. mossambica* as percent of time, spent in water of acclimation temperature (30°C) in total time (10 minutes) spend in avoidance chamber at each test temperature above 30°C. Average response is indicated by line drawn through the mean values (crosses) at each test temperature.

that the avoidance level in running water can be at a different level, closer to lethal threshold than the avoidance level of fish in quiet water.

Discussion and Conclusions

As the observations pointed out would show any undue increase in temperature from the ambient conditions is bound to have some repercussions in the individual organisms and thereby on the total aquatic ecosystem. The individual influences can be either affecting the survival by directly causing mortality or by limiting distribution of motile organisms through avoidance responses or by other behavioural regulating mechanisms. Temperatures can also cause long-term effects on physiological parameters affecting total metabolism, growth and also reproduction.

From this context it is important to judge as to how much the thermal discharges from power plants affect the water temperatures to upset pre-release ecology. It is inevitable that with more power generation thermal pollution also will be on the increase. To take the example of Tamil Nadu, the present power needs are met from 18 hydel stations and 4 thermal stations. Now with the realization that much of the hydel power is already being tapped and that the hydel power capacity is vulnerable in the years of poor rainfall, it is recognized that the situation can be improved only by establishing more thermal plants. Except for the Basin Bridge thermal power station set up in 1909, generating 90 MW the three other thermal power supply unit of the state, namely Neyveli 600 MW (1962), Ennore 450 MW (1970) and Tuticorin 210 MW (1979), were set up much recently only. In the near future Tuticorin Thermal Power Plant (TTPP) would increase its power generation to 630 MW and Neyveli by additional 630 MW, and new thermal units at North Madras and Mettur are expected to generate 630 and 420 MW. In addition to these the Nuclear power plant at Kalpakkam is expected to generate 470 MW. It is likely that the Kalpakkam supply will be further increased (additional 500 MW) and also a new Atomic Station set up at Kudankulam, Tirunelveli generating 1000 MW of power (TNEB, 1979). Some of these power plants have certainly changed the aquatic environment considerably and the extent of these changes is not known. At least with the awareness of the possible ecological changes which can be expected, perhaps we will be in a position to minimize the environmental hazards.

It is obvious that changes of about 8-10°C from ambient, could result in changing the ecology of the effluent area of thermal plants. Some studies on the ecological changes at the effluent area of Tarapur and other places have been made. It is of interest to note that a water volume of $2.45 \times 10^6 M^3$ (*i.e.* a spread of 245 ha of water at 1 m depth) would be heated daily and discharged at the Tarapur power plant (Pillai and Kamath, 1971). An estimate of effluent from the Tuticorin thermal power plant also suggests that a similar quantity of water would be used. The water for the TTPP will be pumped from the Tuticorin Bay in the Gulf of Mannar and let back into the sea. This aspect is complicated by the dumping of flyash into an enclosed area on one side of bay, from where sediments and heavy metals could pass into the adjoining sea. Perhaps the flyash produced can be recycled otherwise for cement industry. And it would appear that the ecological disturbance would be low if the thermal discharges are let further into the open sea so as to avoid serious damage to rich nursery areas of fishes and crustaceans in river mouths, estuaries and bays.

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EFFECTS OF SUSPENSOIDS ON BIOTIC LIFE AROUND THE OUTFALL AREA OF A SULPHITE PULP AND PAPER MILL WASTE IN HOOGHLY ESTUARY

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ABSTRACT

High suspensoids of a sulphite pulp and paper mill wastes formed a compact layer around the outfall in the Hooghly estuary at Hazinagar, near Calcutta. High temperature enhances decomposition of non-conservative material in the subsoil region resulting in evolution of carbon dioxide and hydrogen sulphide. Different tidal phases further complicate the ecosystem. Survival, growth, and reproduction of biotic life are, therefore, affected. Monsoon season improves the condition to some extent. Emergence and propagation of plankton from soils collected from several points indicate maximum density of plankton count during summer (20,360μ/1) and monsoon (227,240 μ/1) respectively in the jars containing soil from the outfall point after an incubation period of four months. During winter the survival of 10-15 mm size young lymnea after exposing them at soilwater interface in cages for 7 days is 100, 10, 60 and 100 per cent at 1.5 km upstream at the outfall and 1.5 km and 2.5 km down stream respectively.

INTRODUCTION

INDUSTRIAL wastes are extremely variable in composition and contain both conservative and non-conservtaive materials along with mineral acids, bases and toxic substances. Effluents of sulphite pulp and paper mill contain such wastes and when disposed into the estuary create a condition (both in water and on soil bed) which is unfavourable for the survival, growth, and reproduction of biotic life around the outfall region. Different tidal phases further complicate the ecosystem. The intensity of disintegration is controlled to some extent due to deposition of monsoon silt. The natural balance is shifted. Available references indicate that the effects of pulp and paper mill wastes are restricted to changes in the abiotic characters (Basu, 1966 ; Ghosh *et al.*, 1977 ; Dhaneshwar *et. al.*, 1970) and on bioassay (Ray, 1961 ; Warren and Doudoraff, 1958). Marier (1973) had attempted to cover all these aspects including effects of sediments in the aquatic ecosystem but not under natural condition in a tidal estuary. The present communication gives the effect of suspensoids of a sulphite pulp and paper mill wastes around the outfall in the Hooghly estuary near Hazinagar (88°15'-88°30' N; 22°45'-23°00' E), 58 km north of Calcutta (Fig. 1) with reference to survival and growth of biotic life.

The authors are indebted to Dr. V. G. Jhingran, former Director of Central Inland Fisheries Research Institute, for suggesting the problem and to Shri B. B. Pakrasi, CIFR Substation, Calcutta, for critically going through the manuscript. Our thanks are also due to Dr. Subba Rao, Zoological Survey of India, Calcutta for identification of benthic organisms.

HYDROLOGICAL FEATURES OF THE ESTUARY AROUND THE OUTFALL

The estuary at this place is subjected to tidal influences. During monsoon it is principally a freshwater discharging river while during dry season the flow is considerably reduced.

The ebb tide flow lasts for a longer time (6.5-8.5 hr during dry season and 7.0-11.6 hr during monsoon) than the flood tide flow (4.0-6.0 hr and 2.5-4.0 hr). The area becomes shallow during low tide period, and the temperature rises thus favouring distintegration of non-conservative materials and in the continuous production of carbon dioxide bubbles from about the outfall to 1.5 km below the outfall. Due to low flow during the dry period and in the transitional periods between high and low tides and vice versa, precipitation of suspensoids occur forming a mat over the bed. But such conditions are not observed in the upstream littoral zones of the estuary. In the recovery zone a fresh condition is also maintained due to low oxygen demand and continuous oxygen in the water.

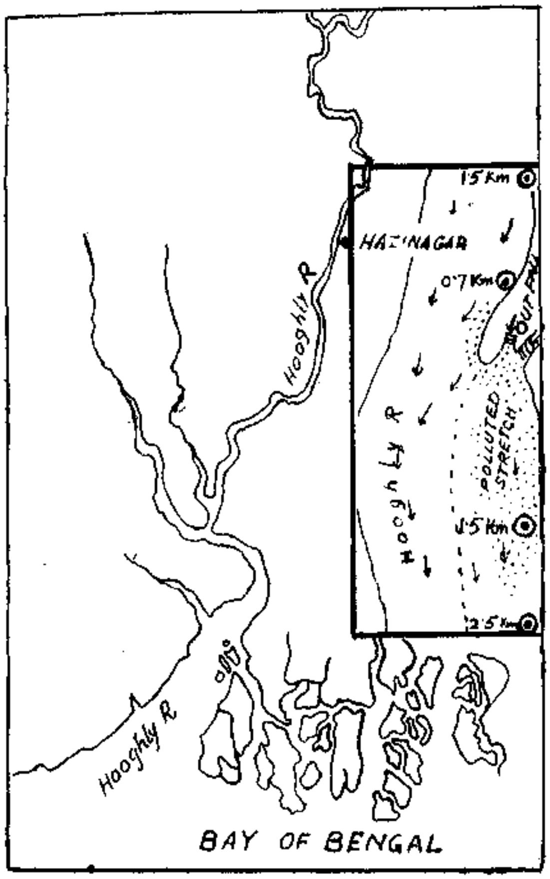

Fig. 1. The location of Pulp and Paper mill affected area around the outfall and sampling centres in the Hooghly Estuary.

Material and Methods

Sampling in a stretch of 4 km was done during the low tide period 1½-2 hours before the high tide. In all the five sampling stations (of Fig. 1) two on either side of the outfall were established in the littoral zone for the study. No samples were collected across the estuary. Seasonal observations, *i.e.*, summer (February-May), monsoon (June-October), and winter (November-January) were made once a month. Biota and soil samples were collected by Ekman dredge from five points of each sampling zones laterally from marginal exposed to inundated area and their averages considered per sq m. Soil temperature was also simultaneously recorded and the averages indicated.

Cage experiments were carried out in 15 × 20 × 25 cm sized cages made of GI wire-nettings using 20 gastropods each of 10-15 mm size belonging to different species. Each cage was tied at points where some water would inundate the cage even during lowest water level. Daily mortality of gastropods was recorded.

For chemical analysis of water, pH was estimated by Beckman pH meter, DO by Beckman oxygen analyser, Carbon Dioxide, alkalinity and sp. conductivity by conventional $N/_{44}$, NaoH, $N/_{50}H_2SO_4$ and conductivity bridge method. Soil pH and organic carbon (Walkley and Black) were estimated following Piper (1950). Oxygen demand (immediate) was estimated by placing an aliquot of sediment collected from different sampling points in a water-filled bottle and following the decline in DO in the water within five minutes. The percentage reduction calculated is taken as oxygen demand value (Hayes, 1964). Such value is considered as immediate oxygen demand. Physical and chemical parameters of soil in relation to biotic life are indicated in Fig. 2.

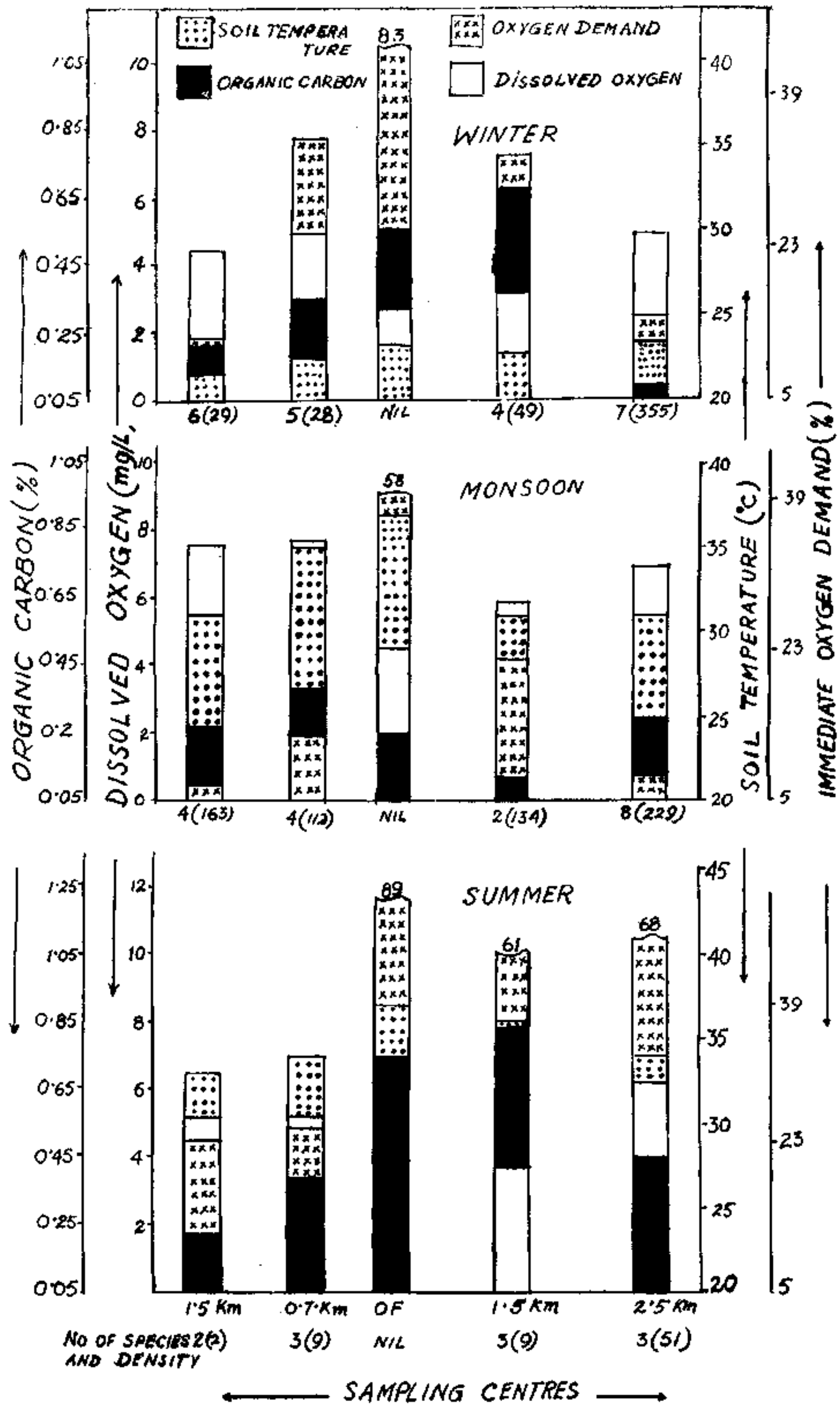

Fig. 2. Physical and chemical parametres of soil and water in relation to biotic life.

Laboratory jar experiments were performed in rectangular 1 litre jars previously laid with a layer of soil from different sampling stations and unpolluted water after filtering through bolting silk cloth No. 25 from the estuary. The mouth of each jar was covered with a clean cloth soaked in water to arrest any foreign material. Loss of water level was compensated by adding distilled water. Random pipette samples were collected fortnightly, uniformly mixed and aliquot examined for plankton and the results were calculated accordingly and expressed as units/litre.

THE PROCESS INVOLVED, SOME IMPORTANT CHARACTERISTICS OF PULP AND PAPER WASTE AND THEIR POLLUTION LOAD

The manufacturing process involved in the sulphite pulp and paper mill is given in details elsewhere (Ghosh *et al.*, 1970).

Raw materials used for manufacture of pulp and paper are bamboo (40-60 t), rags (0-2 t), alum (150-250 kg) ; dyes (2-50 kg), paper savings (0-10 t), soda ash (150-180 kg), magnesium bisulphite and sulphuric acid and clay (2-15 t).

Digestion of chipped cellulosic raw material is done with strong sulphuric acid solution of magnesium bisulphite followed by washing, bleaching and refining of the pulp. Filling, sizing and dyeing of paper etc. are then followed in the manufacture.

The factory discharges in all 7.21 mgd of waste water and the pollution load calculated in terms of BOD_5, total solids, suspended solids and dissolved solids are 4.54, 98.10, 24.30 and 73.80 t/day respectively. The waste is acidic in reaction (pH 5.3-6.9). Do is always found to be absent. Oxygen demanding material is quite high as indicated by their average values—BOD_5, 986 ; 30 mts. permanganate value, 1,201 and 3 mts permanganate value 370 mg/l. In rare cases chlorine waste with high chlorine content 135 mg/l (average value) is discharged through a separate outlet 150 m above the main outfall. Basu (1966) observed pH 5.8-6.4, Lignin and suspended solids 1,000 and 1,990 mg/l respectively and BOD_5, 375 mg/l. The total pollution loads estimated by him for BOD_5 were 11,250, suspended solids 59,700 and lignin 30,000 lbs at the discharge rate of 3,000,000 gallon/day.

EFFECTS OF WASTE WATER ON THE ECOSYSTEM

1.5 km above the outfall

The values (range & mean) of major physico-chemical parameters of Water and soil in summer, monsoon, and winter seasons are as follows. Species formed the biotic community in the above seasons at each centre with their density in the brackets are also given. Physico-chemical characteristics of the substratum in relation to living organisms are given in Fig. 2.

Water

pH—8.3, 7.8 and 8.0.

DO—4.5-6.0 (5.15), 5.1-9.12 (7.58) and 3.07-7.2 (4.41) mg/l.

Alkalinity—80-84 (82), 65-96, (80) and 125-152 (143) mg/l.

Sp. conductivity—496-862 (725), 385-731 (567) and 499-731 (608) m. mhos.

Soil

Temperature—32.0-34.0° (33.0°C), 30.5-32.0°C (31.2°C), 20.0-24.5°C (21.6°C).

pH—6.8-7.2 (7.0), 7.3, 7.0-7.4 (7.3).

Organic Carbon—0.21-0.24% (0.22%), 0.13-0.37% (0.28%), 0.21%

Oxygen demand—20.9-26.0% (2.34%), 3.0-11.3% (7.3%), 8.3-17.5% (12.0%)

Sp. Conductivity—434, 292, 335 m. mhos,

Biota

Biotic life (μ/sq. m.) comprised of *Macrobrachium* sp. (2) and *Melanoides lineatus* (Gray) (2) ; *Macrobrachium* sp. (1), *Melanoides granifera* (Lam) (40), *Stenothyra deltae* (Benson) (2), *M. lineatus* (Gray) (120) ; and Eel (1), Acetor sp. (1), *M. tuberculatus* (Muller) (4), *Thiara scabra* (Muller) (1), *M. lineatus* (Gray) (17) and *Macrobrachium* sp. (3).

0.7 *km above outfall*

Water

pH—8.3, 7.7-8.0 (7.8) and 8.0-8.2 (8.1)

DO—4.64-5.48 (4.98), 4.96-10.4 (7.7) and 3.75-6.8 (4.87) mg/l.

Alkalinity—22-86 (84), 65.3-86 (75.6) and 130-148 (139) mg/l.

Sp. Conductivity—578-992 (785), 386-478 (424) and 514-661 (592) m. mhos.

Soil

Temperature—34°C, 30.5-32.0°C (31.2°C) and 21-24°C (22.5°C)

pH—6.3, 7.3 and 6.8-7.6 (7.2)

Organic Carbon—0.39, 0.37-0.4% (0.38%) and 0.35%

Oxygen demand—20-32% (26%), 10-18.3% (13.1%) and 34.0-38.1% (35.7%)

Sp. conductivity—496, 338-1389 (863) and 397-510 (453) m. mhos.

Biota

Biotic life (μ/sq.m) comprised *Macrobrachium* sp. (1), *Lymnea luteola* f: ovalis (Gray) (1), and *M. granifera*) (Lam) (7) ; *Assiminea francessii* (Wood) (7), *M. granifera* (Lam) (4), *M. lineatus* (Gray) (99), *L. luteola* f: ovalis (Gray) (2) ; and *M. lineatus* (Gray) (12), *Thiara seabra* (Müller) (7), *A. francessii* (Wood) (1), *Stenothyra deltae* (Benson) (1) and *M. granifera* (Lam) (7).

Outfall

Water

pH—6.8-8.0 (7.3), 6.4-7.6 (6.9) and 7.2-8.1 (7.6)

DO—nil, 2.0-7.0 (4.6), nil-4.32 (2.67) mg/l.

Alkalinity—82-180 (131), 65.3-82 (73.6) and 124-144 (134) mg/l.

Sp. conductivity—1736-2315 (2025), 1751-4085 (2606) and 1208-2315 (1688) m. mhos.

Soil

Temperature—37.0°C, 32.0°C and 21.0-25.5°C (23.2°C)

pH—6.8, 7.3 and 6.8-7.4 (7.1)

Organic carbon—0.75, 0.25 and 0.55%

Oxygen demand—82.8-95.6% (89.2%), 36-99% (58.1%) and 76.1-87.3% (82.9%)

Sp. conductivity—1543, 827 and 1262 m. mhos.

Biota

absent.

1.5 *km below the outfall*

Water

pH—7.1-8.2 (7.7), 7.2-7.9 (7.5) and 7.0-8.0 (7.6)

DO—1.39-8.2 (3.83), 3.08-9.68 (5.85) and nil-6.1(3.16) mg/l.

Alkalinity—72-86 (79), 86-89.8 (87.9) and 124-148 (186) mg/l.

Sp. conductivity—1068-1262 (1165), 631-926 (808) and 631-992 (813) m. mhos.

Soil

Temperature—36.0°C, 31.5°C and 21.0-24.5°C (22.7°C)

pH—6.8, 7.1 and 6.6-7.4 (7.0)

Organic Carbon—0.84, 0.12 and 0.67%.

Oxygen demand—55.5-66.0% (60.7%), 20.0-25-39% (22.2%) and 33.5%

Sp. conductivity—1367, 603 and 650 m. mhos.

Biota

Biotic life (μ/sq. m.) comprised *Macrobrachium* sp. (3), *Megalopa larvae* (3) and *M. granifera* (Lam.) (3) ; *M. lineatus* (Gray) (132), and *M. granifera* (Lam.) (2) ; *Thiara scabra* (Müller) (8) *M. lineatus* (Gray) (35), *A. francessii* (Wood) (4) and *Macrobrachium* sp. (2).

2.5 km below the outfall

Water

pH—8.0-8.3 (8.1), 7.7-8.0 (7.8) and 8.0-8.2 (8.1)

DO—4.52-7.95 (6.29), 4.32-10.16 (7.04) and 3.86-6.8 (4.85) mg/l.

Alkalinity—82-88 (85), 89.8-132 (106.6) and 132-156 (144) mg/l.

Sp. conductivity—578-817 (697), 496-1157 (815) and 556-631 (1588) m. mhos.

Soil

Temperature—34.0°C, 31.5°C and 23.0-24.0°C (23.5°C)

pH—7.6, 7.5, and 6.9-7.6 (7.16)

Organic Carbon—0.45, 0.29 and 0.09 %

Oxygen demand—57.8-78.6% (68.2%), 4.5-10.9% (7.53%) and 11.1-19.0% (15.3%).

Sp. Conductivity—748, 555 and 710 m. mhos.

Biota

Biotic life (μ/sq.m.) comprised Megalopa larvae (39), Chironomid larvae (2), *M. lineatus* (Gray) (1), *M. granifera* (Lam.) (8); Megalopa larvae (50), *Macrobrachium* sp. (13), *M. granifera* (Lam.) (54), *M. lineatus* (Gray) (41), *M. tuberculatus* (Müller) (24), *Vivipara dissimites* (Müller (6), *A. francessii* (Wood) (26), *Vivipara bengalensis* (Lam.) (15) ; *Macrobrachium* sp. (25), *Thiara scabra* (Müller) (15), *M. lineatus* (Gray) (170), *M. tuberculatus* (Müller) (45), *Vivipara dissimilis* (Müller), (20), *A. francessii* (Wood) (35), and *Vivipara bengalensis* (Lam.) (45).

Other Observations

From February onwards gas bubbles were observed to be emitted in the stretch mainly from the outfall to 1.5 km downstream in a wider area and slightly above the outfall. Production of gas was more intense and continuous during March-May but ceases completely with floods. The average estimated values of carbon dioxide above the outfall ranged between 3.5-15.5 mg/l while below the outfall the values ranged between 13.5 and 25.5 mg/l. When the littoral zone gets almost exposed with the fall in the water level during low tide, bubbles of carbon dioxide was observed. The concentration of carbon dioxide could not go up perhaps due to its poor solubility under high temperature and movement of water. Hydrogen sulphide gas could not be detected in the water, but however, immediately below the percipitation zone, black layer of sulphide was observed and detected. It is thus possible that sulphide produced from organic decomposition diffuse out and get oxidised at the soil water interface and settle. Reduced iron was also precipitated as ferric iron.

Jar Experiment

Experiments done in the laboratory have shown that emergence and propagation of plankton when soil from different zones comprising 1.5 and 0.7 km above the outfall, the outfall and 1.5 and 2.5 km below the outfall were kpet in estuarine water free from any pollution. The dominant species recorded in each zone during the summer season were Aukistrodesmus, Oscillatoria, Euglena and Closterium (1.5 km above the outfall) ; Navicula, Oscillatoria and Symbella (0.7 km above the outfall) ; Euglena (outfall) ; Oscillatoria (1.5 km below the outfall) ; Oscillatoria (2.5 km below the outfall). In the monsoon season Euglena, Pinnularia and Closterium (1.5 km above the outfall) Cymbella and Closterium (0.7 km above the outfall) ; Closterium and Navicula (outfall) ; Closterium and Euglena

(1.5 km below the outfall) ; Navicula and Oscillatoria (2.5 km below the outfall) ; and in the winter season Euglena (1.5 km above the outfall) ; Oscillatoria and Euglena (0.7 km above the outfall) ; Euglena (outfall) at the first three zones ; and at zones 1.5 and 2.5 km below the outfall plankton density was poor. Maximum plankton count was 20, 360, and 227, 240 u/l during summer and monsoon respectively after an incubation period of 4 months in the jars containing soil from the outfall points. It is interesting to note that although the number of species encountered were much less at the outfall soil their density was appreciably high, indicating the characteristics of organically rich soil.

Cage experiment

Seven days cage culture of young gastropods 10-15 mm size done in winter at the soil water interface have shown 100, 10, 60 and 100% survival in the unpolluted (1.5 km above the outfall), outfall, below the outfall (1.5 km below the outfall) and at recovery zone (2.5 km below the outfall) respectively.

Discussion

Effects of both highly conservative and non-conservative suspensoids brought with the effluent of sulphite pulp and paper mill in an aquatic ecosystem are long term. With favourable temperature decomposition of settled organic matter increases resulting in the reduction of dissolved oxygen at the soil water interface. Carbon dioxide gas is largely produced and bubbles up. The diffused hydrogen sulphide possibly gets oxidised partially at the top layer and a few mm below the substratum soil leaving huge mass of anaerobic zone of unsaturated inorganic and organic (mainly carbonaceous) materials at the soil-water interface. This is continuous process even when the water recedes and large areas get almost exposed during low tide. All these collectively shift the equilibrium of the ecosystem where settling of invertebrate larvae is affected resulting in the absence of any benthic organisms serve as fish food. The equilibrium of such an aquatic ecotope is shifted during monsoon due to precipitation of enormous quantity of silt brought by run off and also due to flushing during tidal phases (especially spring and bore tides). Such phenomena were prevailing at the outfall zone and the 1.5 km stretch below the outfall. Organic carbon was high during summer (0.75%) followed by winter (0.55%), values of oxygen demanding materials were 89.2% and 82.9% in summer and winter months respectively. DO was nil during both the seasons on certain days. In monsoon, however, improvement, possibly due to monsoon silting, was noticeable (oxygen demand 58.1%) though no biotic life was present. Such changes in the balance of ecosystem during summer as well as in winter (partially) were unfavourable for well being of biotic life. Result of settleable solids of pulp and paper mill contributes to deoxygenation of water at the soil water interface and a few mm below the river bed. This help in elimination of oxygen dependent species of invertebrates in the affected zone (Alabaster, 1972 ; Pearson, 1972 ; Waldichuk, 1962 ; Wilbern, 1969). Almost a similar condition persisted at the zone 1.5 km below the outfall where organic carbon was respectively 0.64 and 0.65% during summer and winter seasons and corresponding oxygen demand 60.7 and 43.5% respectively. At this zone value of organic carbon came down to 0.12% with much lower oxygen demand in the bottom mud during monsoon. Average value of DO in the water never reached below 3 ppm.

Although presence of some biotic life was recorded during summer yet they are in poor density. In winter months there was some improvement in density of biotic life reaching maximum in monsoon, perhaps for the reason that pollution impact was evidenced from oxygen demand was reduced. These various parameters which possibly accrue to this condition are monsoon silting, continuous supply of oxygen from the overlying water and breeding phase of molluscs. In a wider area between the zones of outfall and 1.5 km below the outfall, the pollution effect is caused in two ways, *i.e.* direct pollution from waste water which acts for short duration and indirect pollution resulting from decay of settled putrescible materials. In case of direct pollution the waste water moves to and fro, laterally, with the fall and rise of water level during the tides. In indirect pollution the area receiving the suspensoids always remain in an anaerobic state emitting carbon dioxide, hydrogen sulphide, etc. continuously whether the area remain exposed or under water. Such phenomenon is more pronounced during summer and partially during winter.

The zone 0.7 km above the outfall is located on the main flow of the estuary where dissipation of the effluent takes place. The precipitation of suspensoids are not so appreciable and can settle only during neap tide and transitional periods of tides. Organic carbon was 0.39, 0.38, and 0.35% during summer, monsoon, and winter respectively. The corresponding value of oxygen demand were less—26, 13.1 and 35.7%. The flow of water being rapid DO at no time showed nil value, average being 4.9 mg/l. Although the biotic life was present but in low density. They are largely affected by bore and spring tidal phases. The higher density of biota in monsoon possibly was due to their breeding phase.

The zone 1.5 km above the outfall is topographically similar to zone 0.7 km. Oxygen demand of soil came down to 7.3% in monsoon. Number of species of biota was more during winter but their density was more in monsoon. This may be on account of impact of pollution being less and the breeding period. This zone is also affected by rapid flow during tidal phases (Bore and Spring tide).

The last zone, 2.5 km below the outfall, is influenced by pollution only in summer as oxygen demanding material of soil was high (68.2%) and organic carbon content was 0.45%. Its effect was possibly neutralised to some extent by the presence of moderately high concentration of oxygen in the water. The number of bottom biota in summer was higher than observed in other centres. During monsoon values of organic carbon were further lowered (0.29%) and was lowest in winter (0.09%). The oxygen demand during these two seasons were respectively 7.5 and 15.3%. In both the seasons the number of species of organisms and their density were highest, thereby, indicating that in both the seasons the zones were free from pollution.

Presence of organic carbon has a direct influence on the growth and propagation of plankton as evidenced by jar experiments. Plankton, although initially had grown, grows slow in the polluted soil at the initial stage perhaps due to anaerobic state, but it developed highest concentration in culturing for 3-4 months. This is an indication that it may take 3-4 months for whole aquatic ecosystem to attain equilibrium.

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EFFECT OF INDUSTRIAL POLLUTION BY SODA PROCESS PULP AND PAPER MILL WASTE ON THE PRIMARY PRODUCTIVITY OF THE HOOGHLY ESTUARY NEAR TRIBENI

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Abstract

Characteristics of trade effluents from a soda process pulp and paper mill and their impact on certain water quality parameters, plankton, gross (GP) and net (NP) primary productivity of the Hooghly Estuary with the interacting effect of various seasons and tidal phases (1975) during low tide condition have been highlighted. Oxidisable organics and predominantly alkaline nature of the effluent played a positive role in changing the water quality and biological equilibrium of the estuarine environment along the marginal stretch of 1.25 km below the outfall. The water qualities like temperature, turbidity, alkalinity, dissolved oxygen and oxygen consumption remained affected even at 1.25 km downstream, particularly during neap (NT), spring (ST) and bore (BT) tidal phases of summer months.

The primary productivity determined by light and dark bottle (LDB) technique, indicated no recovery within the stretch during NT of various seasons, while recovery was distinctly noted during ST/BT of winter and monsoon. Summer condition intensified the degree of pollution as reflected by reduction of primary productivity even during ST/BT condition. On an annual average basis, 86% and 49% reduction in GP and NP at 250 m below and 40% and 49% reduction at 1.25 km downstream were indicated during NT, whereas recovery to the extent of 121% and 300% in GP and NP were noted at 1.25 km below the outfall under ST/BT condition.

While the appreciable reduction in GP and NP (96 and 100%) noted at the outfall area during monsoon may be attributable to high turbidity, low alkalinity, nutrients and plankton population, the marked reduction in GP and NP during summer (65 and 100%) and winter (64% and 100%) is contributed mostly by the trade effluent. Phytoplankton abundance showed a reduction of 58-63% in dry season. Remedial measures for abatement of pollution have been suggested to safeguard the development of coastal aquaculture in this estuarine belt.

Introduction

Mortality of fish, fish eggs and larvae, reduced growth rate of fish and production of quality and healthy fish and prawn seeds, slow rate of maturity and inhibition of spawning due to development of physico-chemical barriers for migration of anadromous and catadromous species, damage of the spawning ground due to organic deposits, destruction of both surface and bottom fish food organisms and qualitative changes in their composition and bioaccumulation of heavy metals, organochlorine pesticides, radionucleides, detergents and high boiling polycyclic aromatic hydrocarbons in the aquatic food chain are some of the serious hazardous effects of water pollution in the natural estuarine ecosystems of the country (FAO, 1967; Gopalakrishnan *et al.*, 1970; Ling, 1972), which are threatening the development of estuarine and coastal aquaculture in reality.

The Hooghly, a major estuary, is situated in the more productive zone of the east coast of India and has a large tidal belt (296 km) and area (0.8 mill ha). It is a potential area for development of brackishwater and coastal aquaculture due to its high marine faunistic richness (Gopalakrishnan, 1971). But, it faces major and complex pollution problems since it is exposed to various pollutants discharged from industrial (0.43 mill m^3/d) and domestic and municipal sources (0.85 mill m^3/d) in a 92 km stretch between Dumurdaha and Birlapore (Ghosh *et al.*, 1973).

The pollution in the Hooghly Estuary is mainly organic in nature (Jhingran and Ghosh, 1978) due to drainage of pulp and paper mill effluents to the tune of 86% (0.16 mill m^3/d) of the total discharge of purely industrial organic wastes (about 0.205 mill m^3/d). The various types of pulping processes *i.e.* soda, sulphate (kraft) and sulphite, produce wastes of varying physico-chemical characteristics due to variations in the process technology and bleaching practices (Basu *et al.*, 1973 ; Ghosh *et al.*, 1977, 1978). The present communication deals only with the impact of soda process pulp and paper mill effluent on the *in situ* primary productivity and certain environmental parameters of the Hooghly Estuary around the outfall near Triberi under different tidal phases and seasons, as the tidal and seasonal influences are the main variables governing the mixing pattern, dispersion and retention of pollutants in the dynamic estuarine system and measure of primary productivity is an important index for the estimation of pollution effect indicating the ecological imbalances in a water body (Odum, 1960).

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Fishery Resources of the Hooghly Estuary

172 species of fish have been recorded of which 73 occupy freshwater zone and 99 belong to higher salinity zone. Lower zone is rich in fishery resources and accounts for 70-80% of the total annual landing of the entire estuary. *Hilsa ilisha*, *Lates calcarifer*, *Polynemus paradesius*, *Mugil parsia*, *M. tade*, *Polynemus indicus*, *Pama pama*, *Sillago panijus*, *Rhinomugil corsula* are some of the commercially important fishes (Gopalakrishnan, 1968). The giant freshwater prawn (*Macrobrachium rosenbergii*, deMan) contributes a mjor share to the prawn component in the bheris of West Bengal. The most commonly available seeds are *M. parsia*, *M. tade*, *R. corsula* (20-45 mm) during January-March with peak in February. Fry of *P. tetradactylus* (5-8 mm) and post-larvae of threadfins (*P. paradesius*, *P. indicus*) are available in March. Mullets are available throughout the year in the lower zone where salinities are high. *M. rosenbergii* migrates to the estuary for breeding in areas where salinities are in the range of 5-20 ppt. The species breeds mostly during March-May (Rao, 1967).

Principal Products and Capacity of Production

The tissue mill is located on the right bank of the freshwater zone of the Hooghly Estuary (Fig. 1) at Tribeni (60 km upstream of Calcutta). It produces 17.4 tonnes of different grades of tissue papers per day under normal operation employing soda process.

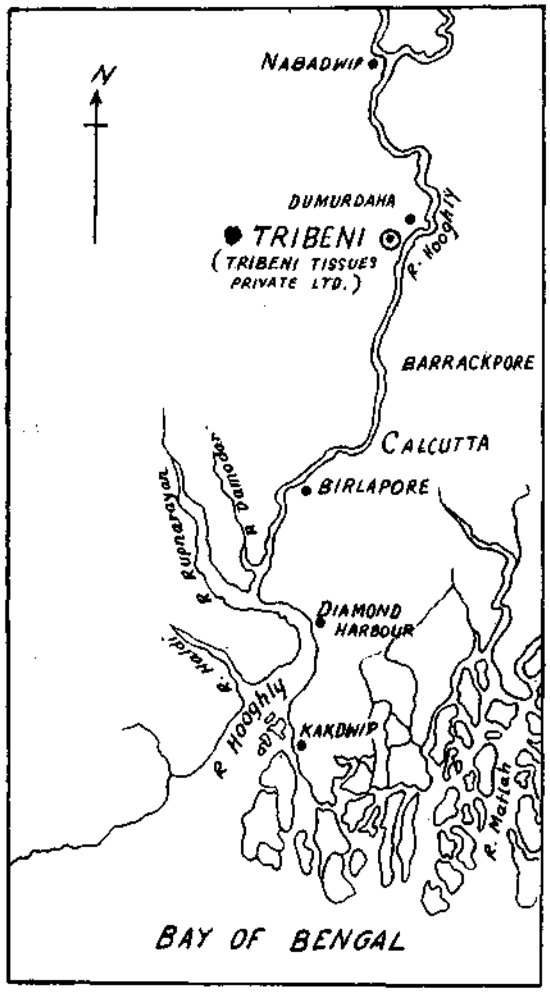

Fig. 1. The location of pulp and paper mill (Soda process) at Tribeni in Hooghly Estuary.

Raw Materials and Chemicals Used in the Manufacture of Pulp and Paper and the Process Involved

Rags (hemp) are the principal raw materials, while caustic soda, sodium sulphide, bleach and dyes constitute the main chemicals used as process materials. The details of the manufacturing process have been elaborated by Basu *et al.* (1973) and Ray *et al.* (1978). The process is almost similar to that of kraft (sulphate) process excepting that a very low concentration of sodium sulphide is used in the soda pulping process.

Sources and Volume of Waste Waters

A total of 10,318 m^3/d of waste water are drained from the mill of which 275 m^3/d are directly discharged into the estuary through two separate outlets located at a distance of about 250 m from each other. The upstream outlet No. 1 carries 2,398 m^3/d of wastes representing waste black liquor and washings from cooking operation at the Digester house in addition to the washings from Breaker house. The downstream outlet No. 2 drains 360 m^3/d from Chalk plant. Other than the discharge from two outlets, 70% of the wastes (7,650 m^3/d) derived from Breakers, Bleachers, Filter and Paper machine House are directed to the nearby paddy fields through a canal. About 575 m^3 of waste water per tonne of products per day are discharged and the water requirement per tonne of product is almost same as the volume of waste discharged.

Material and Methods

Effluents drained into the estuary directly through outlets No. 1 and 2 were collected for their analyses. Four sampling zones were selected along the marginal stretch of the Hooghly (near Tribeni) around the effluent discharge points of the mill *i.e.* 450 m above the 1st outfall, upstream outfall (1st), downstream outfall (2nd) about 250 m below the 1st outfall and 1.25 km below the 1st outfall to study the pollution effect on the estuarine ecosystem. Water samples were drawn from a depth of 15-20 cm from the surface during low water levels of neap (NT), spring (ST) and bore (BT) tidal phases of three distinct seasons, summer (March-June), monsoon (July-October) and winter (November-February). Since no vertical gradient with respect to salinity and temperature was recorded in the estuary (Bose, 1956), sampling for measurement of primary production was confined to surface only. Modified basic Winkler's method was employed for determination of dissolved oxygen (DO) using N/80 standard sodium thiosulphate solution. This with other parameters were determined by following methods given in APHA (1965). Plankton samples were collected by filtering 50 litres of water through a plankton net of bolting silk No. 25 XXX. They were preserved in 5% formalin and estimated numerically (no./1) under a microscope using a Sedgewick Rafter counting cell. Water samples were collected in plastic buckets, previously rinsed with estuarine water, for measurement of *in situ* primary productivity. The samples were siphoned into two light and two dark glass-stoppered pyrex bottles (250 ml capacity) previously cleansed with chromic acid (Prasad and Nair, 1960) to measure organic production in each sampling zone. Light and dark bottle (LDB) techniques of Gaarder and Gran (1927) and subsequently modified by Strickland and Parsons (1965) and Strickland *et al.* (1972), were followed to calculate photosynthetic oxygen values to carbon assimilation using a factor of 0.375 /PQ and taking the value of photosynthetic quotient PQ ($+\Delta O_2/-\Delta CO_2$) as 1.2 and respiratory, quotient, RQ ($+\Delta CO_2/-\Delta O_2$) as unity. The bottles were darkened by applying double coating of 'Black Japan' and further covering with black celophane papers to inhibit photosynthesis. The bottles were suspended from a bamboo pole loosely tied to an anchored drum and floats to ensure the fixed position of the bottles from the surface and avoidance of shades (Prasad and Nair, 1960), during the exposure time, which was kept as 3-5 hours during 0900-1600 hours of the day.

Results and Discussion

Characteristics of the waste waters and their pollution load

The effluent discharged from Digester and Breaker house is brownish yellow in colour and offensive in smell. It is having high pollutional characteristics (Table 1). Chalk plant waste from downstream outlets is mostly whitish and at times coloured. It is rich in suspended solids (SS), more alkaline in reaction (av. : pH 8.7 approx. and at times pH exceeds 10.5).

The pollution load (daily average) contributed into the estuary by the combined effluent (2,758 m^3/d) were estimated as 0.30 tonnes (t) BOD, 0.89 t COD ($KMnO_4$), 3.34 t SS, 1.31 t dissolved solids (DS) and 0.61 t lignin based on their average values (98, 291, 1089, 427 and 200 mg/l). The pollution load from Digester and Breaker house was significantly higher than Chalk plant.

Hydrobiological impact on the Hooghly Estuary

Variations in the physiogeography and hydrography of the estuarine environment are main factors controlling the development of estuarine or coastal aquaculture. There is a decrease in tidal oscillations from north to south which are well developed in the northern-most Hooghly Estuary, but are comparatively small in the southern-most estuary like the Cauvery. Due to funnel shape of the Hooghly near its mouth, 'bore tide' is a peculiar phenomenon observed in this estuary, which results much turbulance during this phase. The runoff and direct precipitation are greater than evaporation making the Hooghly a positive estuary of mixohaline in character. Annual runoff (10.3 m) is highest in the Hooghly compared to that (0.12 m-0.69 m) of other estuarine systems of the country. Duration of flood tide is less in dry season and monsoon (2.5-6.0 hr), whereas ebb tide lasts longer (6.5-11.5 hr).

The mean difference between high and low tide levels during NT and ST ranges 0.27-4.02 m and 0.62-6.43 m respectively in the various estuarine systems (Pantulu and Bhimachar, 1964, Per. comm.). Such naturally occurring varied phenomena result in drastic variations in the estuarine environment. The compensation depth in turbid estuaries lie within 3 m (Qasim *et al.*, 1968), which is also applicable in the Hooghly Estuary whose turbidity and depth in the marginal stretches are in the ranges of 108—> 1000 and 2.2-2.8 m respectively.

was not felt up to 1.25 km below the outfall during NT of summer and winter indicating persistence of the pollutants even up to the stretch, although an increase in nitrate and phosphate was noted in the outfall regions during NT and ST/BT. No adverse effect on pH was noted at 1.25 km below during different tidal phases of various seasons indicating high buffering capacity of the estuary. Higher temperature, alkalinity, oxygen consumption (OC) and phosphate and less DO during NT and higher turbidity, pH, chloride and nitrate recorded during ST/BT of various seasons

TABLE 1. *Characterisation of the combined effluent drained through two major units of the soda process pulp and paper mill located on the right bank of the Hooghly Estuary*

Parameters observed	Effluent from Digester and Breaker House			Effluent from Chalk plant		
	Upstream outlet (No. 1)			Downstream outlet (No. 2)		
	Minimum	Maximum	Mean	Minimum	Maximum	Mean
Air temperature (°C) ..	21.5	40.0	30.1	21.5	36.0	31.4
Effluent temperature (°C) ..	21.0	32.5	30.0	21.0	33.5	30.5
Turbidity (Silica scale) ..	120	>1000	720 (approx)	<85	>1000	620 (approx)
pH ..	6.9	9.5	8.2	7.0	>10.5	8.7 (approx)
DO (mg/l) ..	0.0	6.7	2.4	0.6	7.7	4.5
$KMnO_4$ demand (mg/l)						
½ hr at 100°C ..	43	1390	383	9	1280	206
3 min at ambient temperature ..	0	680	117	0	160	57
BOD_5 at 20°C ± 1°C (mg/l) ..	19	368	132	9	250	64
Total alkalinity as $CaCO_3$ (mg/l) ..	140	2070	582	50	1232	387
Carbonate alkalinity as $CaCO_3$ (mg/l) ..	106			10	515	97
Hydroxide alkalinity as $CaCO_3$ (mg/l) ..	—			10	1024	352
Chloride as Cl (mg/l) ..	20	226	94	30	348	111
Dissolved solids (mg/l) ..	46	980	587	78	750	248
Suspended solids (mg/l) ..	304	2698	980	156	2542	1212
Nitrate as NO_3—N (mg/l) ..	0.40	1.83	0.82	0.30	0.83	0.48
Phosphate as PO_4 (mg/l) ..	0.45	2.88	1.06	0.17	0.61	0.42

The region near the outfall indicated higher temperature during neap tide (NT: 23.5-33.0°C) compared to spring/bore tide (ST/BT: 24.8-31.8°C) and upstream of the outfall. Chloride content during NT and ST/BT near the outfall were recorded as 8.4-123.0 mg/l and 17.0-170.0 mg/l against the corresponding values of 8-20 mg/l and 9.0-47.0 mg/l noted at the upstream. The recovery of chloride at the downstream stretch are mainly contributed by the trade effluents (Table 1, 2).

In the upstream, increasing trend in gross production (GP), net production (NP), phyto and zooplankton during NT of winter and decreasing trend during NT of summer have been noted compared to ST/BT which may be due to comparatively higher DO (6.6-7.8 mg/l)

Table 2. *Physico-chemical conditions of the Hooghly Estuary around the outfall of a pulp and paper mill (soda process) at Tribeni during low water level of various seasons and tidal phases* (1975)

Sampling Zone	Period	Temp. (°C)	Turbidity (units)	pH	Total alkalinity as $CaCO_3$ (mg/l)	Oxygen consumption for ½ hr OC at 100°C (mg/l)	Dissolved oxygen (mg/l)	Nitrate as N (mg/l)	Phosphate as PO_4 (mg/l)
					Neap Tidal Phase (NT)				
450 m above outfall	Summer	30.0-32.5 (31.2)	116-424 (270)	8.3-8.3 (8.3)	97-152 (125)	4-11 (7)	6.4-6.6 (6.5)	0.05-0.12 (0.10)	0.05-0.25 (0.15)
	Monsoon	27.6-32.0 (29.9)	158->1000 (664 approx)	8.0-8.3 (8.1)	57-113 (82)	7-38 (16)	5.8-6.3 (6.1)	0.04-0.11 (0.06)	0.06-0.61 (0.22)
	Winter	21.0-28.5 (24.7)	<85-145 (115 approx)	8.2-8.3 (8.2)	211-270 (240)	4-8 (6)	6.6-7.8 (7.2)	0.04-0.13 (0.08)	0.10-0.12 (0.11)
Outfall (1st + 2nd)	Summer	30.5-33.0	108-833	8.0-8.6	167-365	13-256	3.0-5.9	0.05-1.00	0.08-1.82
	Monsoon	27.6-32.8	360->1000	8.2-9.0	60-234	7-118	3.1-6.3	0.02-0.50	0.09-1.53
	Winter	23.5-29.0	115-248	8.5-9.3	206-480	35-210	3.1-6.2	0.06-0.21	0.23-1.74
1.25 km below outfall	Summer	30.8-32.5 (31.6)	146-340 (283)	8.3-8.3 (8.3)	125-157 (141)	9-32 (21)	5.8-6.1 (6.0)	0.06-0.15 (0.10)	0.11-0.34 (0.22)
	Monsoon	27.6-32.5 (30.1)	238->1000 (714 approx)	8.1-8.3 (8.2)	60-87 (79)	3-9 (7)	5.3-6.2 (5.8)	0.03-0.12 (0.06)	0.07-0.17 (0.10)
	Winter	22.0-27.5 (24.5)	<85-205 (145 approx)	8.2-8.2 (8.2)	187-234 (210)	12-14 (13)	5.6-7.6 (6.6)	0.06-0.20 (0.13)	0.08-0.41 (0.27)
					Spring/Bore Tidal Phase (ST/BT)				
450 m above outfall	Summer	29.0-31.0 (30.3)	217-550 (339)	8.2-8.5 (8.3)	97-266 (179)	4-20 (12)	5.4-6.0 (5.9)	0.04-0.10 (0.07)	0.09-0.18 (0.14)
	Monsoon	29.5-31.5 (30.3)	188-800 (551)	8.0-8.2 (8.1)	79-99 (86)	4-9 (6)	5.9-6.4 (6.1)	0.02-0.08 (0.05)	0.06-0.16 (0.11)
	Winter	20.5-22.5 (21.5)	115-265 (190)	8.3-8.3 (8.3)	109-172 (140)	3-5 (4)	5.2-7.0 (6.1)	0.04-0.10 (0.07)	0.06-0.16 (0.16)
Outfall (1st + 2nd)	Summer	30.5-31.8	234-650	7.5-8.6	131-304	8-226	4.1-6.2	0.04-0.67	0.05-0.61
	Monsoon	30.0-31.8	320->1000	8.1-9.8	84-380	8-204	3.3-6.3	0.02-0.43	0.07-0.88
	Winter	24.8-26.5	315-1000	8.7-9.0	140-416	30-152	4.1-5.7	0.05-1.33	0.55-0.88
1.25 km below outfall	Summer	29.5-31.8 (30.8)	307-500 (387)	8.2-8.3 (8.2)	112-274 (199)	5-21 (14)	4.5-6.3 (5.4)	0.03-0.17 (0.10)	0.09-0.34 (0.20)
	Monsoon	29.0-31.0 (30.1)	250-1000 (672)	8.1-8.2 (8.2)	73-99 (85)	9-9 (9)	5.7-6.1 (5.9)	0.02-0.08 (0.05)	0.08-0.17 (0.11)
	Winter	20.0-23.5 (21.7)	135-360 (248)	8.3-8.4 (8.3)	119-244 (181)	7-12 (10)	4.7-6.7 (5.7)	0.03-0.71 (0.37)	0.08-0.12 (0.10)

and less turbidity (min. <85) and temperature (av.: 21.5°C) in NT of winter and higher temperature (max. 32.5°C) in NT of summer, while in the downstream stretch, increasing trend in NP and phyto and zooplankton was recorded mainly in NT of winter associated with low turbidity (min <85) and high DO (max. 7.6 mg/l) and phosphate (1.74 mg/l) compared to ST/BT. However, much decline in NP has been observed during NT (—100%) of summer compared to that in ST/BT (—80%).

Overall decline in GP, NP and phytoplankton during NT of various seasons was to the tune of 96, 100 and 62% respectively, while it was less in GP (—79%) and almost identical in respect of NP and phytoplankton during ST/BT condition. Recovery of GP (+17%) and NP (+381%) in ST/BT of winter and GP (+103%) and phytoplankton (+71%) in monsoon has been noted at 1.25 km downstream (Table 3). Comparatively more favourable environment like lesser temperature, alkalinity and OC and higher nitrate in ST/BT of winter than NT and lesser temperature in ST/BT of monsoon might be conducive for the recovery during ST/BT condition.

More unfavourable water quality with respect to temperature (max. 33°C), OC (max. 256 mg/l) and DO (min. 3.0 mg/l) observed during NT of summer compared to those during NT of winter and ST/BT of both summer and winter might be attributable to non-recovery of primary productivity even up to 1.25 km below during NT of summer and winter (Table 3) and more reduction in NP (100%) in the downstream during summer compared to NT of winter (64%). Less DO (5.4-6.0 mg/l) in the upstream during ST/BT of summer compared to NT of summer may be attributable to higher chloride (9-47 mg/l) in ST/BT than NT (9-19 mg/l).

Phytoplankton population was highest in winter (40-78 no./l) and lowest in monsooh (5-11 no./l) irrespective of the influence of different tidal phases and more adverse effect was noted in NT compared to ST/BT. On the contrary to the adverse situation noted in NT, the ST/BT condition indicated a better picture as sign of recovery (5%) was noted at 1.25 km below even during summer. The maximum damage to the extent of 63% and 58% were noted during winter and summer respectively near the outfall. Similar seasonal trend in zooplankton abundance was noted around the outfall.

On an annual average basis, no recovery of GP, NP and plankton population was noted during NT up to 1.25 km below, whereas a distinct recovery of GP (+121%) and NP (+300%) could be found in the same stretch during ST/BT condition. Moreover, 86% and 49% reduction in GP and NP at 250 m below and 40% and 49% reduction in GP and NP at 1.25 km below were indicated during NT on an annual average basis. The appreciable % reduction in GP and NP (96,100) noted at the outfall areas during monsoon is attributable to floods associated with high turbidity (360->1000) and low alkalinity (av: 79 mg/l), nutrients and plankton population 4-9 no./l), while marked reduction in GP and NP during summer (65, 100) and winter (64, 100) is mostly contributed by the trade effluents (Table 3).

Ghosh *et al.* (1979, MS) while conducting the studies on organic production of the estuary in a longer stretch between Kalna and Kakdwip showed adverse effect on NP up to Kakdwip which may adversely affect the development of coastal aquaculture around the estuarine belt. Gopalakrishnan *et al.* (1970) indicated complete absence of benthic organisms near the tissue mill outfall. Basu (1965) had also indicated a low primary production in the Hooghly compared to Matlah, which is free from industrial pollution. Since the spawning ground of a number of species notably of *Hilsa ilisha* lie in the neighbouring stretch of the mill and the freshwater prawn, *M. rosenbergii* migrates towards the estuary for breeding, it is

TABLE 3. *Effect of disposal of pulp and paper mill (soda process) effluent on the primary productivity and plankton of the Hooghly Estuary around Tribeni during low water level under neap tidal (NT) and spring/bore tidal (ST/BT) phase*

Zone No. & period	Neap Tide (NT) Primary production (mg C/m³/hr) GP	NP	Plankton population (no./l) Phyto	Zoo	% reduction (—) or % gain (+) GP	NP	Phyto	Zoo	Spring/Bore Tide (ST/BT) Primary production (mg C/m³/hr) GP	NP	Plankton population (no./l) Phyto	Zoo	% reduction (—) or % gain (+) GP	NP	Phyto	Zoo
1. Summer	0.0-14.6 (7.3)	0.0-5.2 (2.6)	10-38 (24)	4-14 (9)	—	—	—	—	10.2-35.9 (22.6)	6.2-7.9 (7.0)	17-61 (43)	6-24 (13)	—	—	—	—
Monsoon	0.0-52.5 (31.5)	0.0-33.3 (8.3)	6-10 (8)	1-6 (3)	—	—	—	—	0.0-10.7 (9.0)	0.0-7.3 (2.4)	5-11 (7)	1-3 (2)	—	—	—	—
Winter	138.5-162.5 (150.5)	65.6-118.7 (92.1)	70-78 (74)	27-49 (38)	—	—	—	—	12.5-91.7 (52.1)	0.0-12.5 (6.2)	40-75 (57)	7-18 (12)	—	—	—	—
2 Summer	0.0-10.4 (5.2)	0.0-0.0 (0.0)	4-20 (12)	2-3 (2)	(—)29	(—)100	(—)50	(—)77	10.2-25.9 (12.5)	0-21.6 (5.4)	5-36 (18)	3-8 (5)	(—)44	(—)23	(—)58	(—)61
Monsoon	0.0-3.1 (2.2)	0.0-5.2 (1.3)	2-8 (4)	0-3 (2)	(—)93	(—)84	(—)50	(—)33	0.0-14.6 (6.6)	0-0 (0)	0-5 (3)	0-2 (1)	(—)27	(—)100	(—)57	(—)50
Winter	43.7-65.6 (54.1)	21.9-43.8 (32.8)	17-34 (25)	8-12 (10)	(—)64	(—)64	(—)62	(—)74	22.9-25.0 (23.9)	0-0 (0)	16-26 (21)	5-21 (13)	(—)54	(—)100	(—)63	(+)8
3 Summer	0.0-9.4 (6.0)	0.0-0.0 (0.0)	13-30 (21)	5-6 (5)	(—)18	(—)100	(—)12	(—)44	5.9-10.2 (8.0)	0-2 (1.4)	12-46 (24)	2-10 (6)	(—)65	(—)80	(—)44	(—)54
Monsoon	0.0-5.2 (1.3)	0.0-0.0 (0.0)	4-9 (6)	0-4 (2)	(—)96	(—)100	(—)25	(—)33	0.0-5.6 (1.9)	0.0-5.2 (1.7)	3-11 (7)	2-5 (3)	(—)79	(—)29	(±)0	(+)50
Winter	39.6	13.6	29	8	—	—	—	—	6.2-121.9 (34.0)	0-0 (0)	9-35 (22)	0-5 (2)	(—)35	(—)100	(—)61	(—)83
4 Summer	0.0-8.3 (4.2)	0.0-0.0 (0.0)	7-32 (20)	5-6 (5)	(—)42	(—)100	(—)17	(—)44	14.1-28.1 (18.4)	0-8.1 (2.0)	30-63 (45)	4-33 (13)	(—)19	(—)71	(±) 5	(—) 0
Monsoon	0.0-8.5 (4.7)	0.0-0.0 (0.0)	3-25 (6)	2-5 (3)	(—)85	(—)100	(—)25	(±) 0	5.2-39.6 (18.3)	0-5.2 (1.7)	4-18 (12)	3-6 (5)	(+)103	(—)29	(+)71	(+)150
Winter	55.2-109.3 (82.2)	26.0-72.9 (49.4)	35-63 (49)	26-29 (27)	(—)45	(—)46	(—)34	(—)29	12.5-109.2 (60.8)	12.5-47.1 (29.8)	37-50 (44)	5-16 (10)	(+)17	(+)381	(+)22	(—16)

1. 450 m above outfall
2. 1st outfall
3. 2nd outfall (250 m below 1st outfall)
4. Extreme below outfall (1.25 km below 1st outfall)

likely that the pollution impact as noted around the outfall of soda process pulp and paper besides other industries like sulphite process pulp and paper mills and rayon industrial complex situated in the same belt might be adversely affecting the spawning and even migration of both the species.

Measures for Abatement of Pollution for Development of Coastal Aquaculture

Since the Hooghly Estuary receives pollutants from various sources and encounters hazardous effects leading to the damage of bottom productivity near the outfall areas which subsequently affects the primary productivity in the main stream, it is necessary to properly treat each type of effluent to maintain suitable water quality for survival, growth and reproduction of plankton and food fish including prawns. Recovery of by-products from waste waters particularly lignin from pulp and paper mill waste, recycling of the waste waters inside the factory, disposal of waste waters such as, distillery, sugar, pulp and paper (particularly soda process) including domestic sewage having high fertility value on agricultural land, restricted use of chlorinated hydrocarbon and organo-mercury compound, suitable low cost treatment methods for removal of suspended solids, BOD and COD from wastes rich in organic matter are some of the important steps warranting implementation at National level to safeguard natural fisheries for development of coastal aquaculture in the country. Water quality criteria should be established for plankton, fish and prawn based on toxicity bioassay study for each type of effluent, chemical, pesticide, detergent and other toxicants. The passage way for migration of movement of fish should contain preferably 75% of the cross-sectional area and/or volume of flow of the estuary (Report of FWPCA, 1968).

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TOLERANCE OF A BRACKISHWATER CLADOCERAN *ALONA TARAPOREVALAE* SHIRGUR AND NAIK TO DIFFERENT SALINITY, TEMPERATURES AND DISSOLVED OXYGEN CONDITIONS

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ABSTRACT

Studies were made on tolerance behaviour of *Alona taraporevalae* Shirgur and Naik under variations in salinity, temperatures and D.O. levels under controlled conditions. It was observed that optimum salinity for these organisms was in the range of 10-12 ppt. This was determined on the basis of comparative rates of proliferation in different salinity media and further correlated by results of second series of experiments which indicated occurrence of sexual females bearing ephippia only in lower and higher salinity media. Under the optimal salinity range, the maximum population density was around 600 organisms per litre within two weeks by parthenogenetic reproduction.

Thermal tolerance studies indicated 49°C as the lowest temperature causative for instantaneous mortality. The consecutive temperatures in the downward scale revealed survival periods in seconds, minutes, hours and days. In all, six thresholds in the temperature scale starting from 49°C and downward have been noted. In the range of 30-31°C, the animals survive continuously but do not reproduce normally. 28-30°C was the optimum range for cultural work.

Observations have been made on D.O. levels in the cultural media in relation to administration of 1, 2 and 3 ml of clear solutions of ground nut oil cake. One ml of solutions contained nearly 18 mg of the solutes. It was observed that below 3.8 ppm. of D.O. levels, the animals do not thrive and to maintain the desired D.O. level, 1 ml of the fertiliser solutions is suitable per one litre of the cultural medium.

INTRODUCTION

IN THE PREVIOUS WORK (Shirgur and Naik, 1977) observations on morphology, taxonomy and ephippial hatching and culture of new cladoceran species *Alona taraporevalae* (Fam : Chydoridae) under laboratory conditions were discussed.

As regards the tolerance behaviour on different environmental factors only preliminary observations had been made and the cultural work was undertaken around 7.5‰ under the temperature range of 27°C - 29°C.

In continuation, this paper deals with the parameters of 3 important environmental factors. From cultural point of view it is very essential to understand the behavioural pattern of *Alona taraporevalae* with regard to environmental factors such as salinity, temperature and D.O. (dissolved oxygen) position of these media.

Except in regard to vital staining technique to observe respiratory surfaces of a few species of *Alona* namely *A. rectangula*, *A. costata*, *A. quandrangularis* and other chydorid species (Dejdar, 1930 a ; Smirnov, 1974) there seems to be no work on varying environmental factors.

Literature in regard to thermal tolerance studies on genus *Alona* in particular and the

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family chydoridae in general is very scarce. The data on the upper lethal temperature for some of the chydoridae is given by Smirnov (1974). As regards other marine cladocerans Ackefors (1971) has reported temperature and salinity studies with reference to *Podon polyphemoides* and *Bosmina coregoni maritima*. Considering the cladocerans in general especially in relation to freshwater forms, Pratt (1943) has given analysis of population development in *Daphnia* at different temperature. Sann Aung (1973) has cited experimental results on thermal tolerance of *Daphnia carinata* King and *Moina macrocopa macrocopa* (Strauss).

However, the details of other *Alona* species specially in regard to temperature of instantaneous mortality to those of survival upto a limit wherein these survive indefinitely are not adequately understood.

The gas exchanges under the optimum environment is carried out by the epipodites of the legs one to fifth, and by the pump chamber. Some species of subfamily chydoridae and Aloninae have processes on the epipodite and some do not. In other instances the ephippia of pelagic Daphnidae are without processes. There are some data available on the uptake of oxygen of chydoridae at 20°C. This information is mainly concerned with energy metabolism. This information becomes very vital especially when one has to regulate administration of fertilisers, especially the organic ones, in water media for culture. Under these conditions, D.O. level closely fluctuates as that of quantum of fertiliser applied.

In the present study observations have been made on salinity, temperature tolerance followed by optimum D.O. requirements which under reduced sublethal level cause mortality. In case of the last factor indirect observations have been made in proportion to administration of various quantities of organic fertilisers such as ground nut oil cake and urea as B.O.D. (biological oxygen demand) plays very important role. Observations have been made on respiratory surfaces as can be demonstrated by vital staining with a pink solution of potassium permanganate ($KMnO_4$), (Dejdar, 1930 a).

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MATERIAL AND METHODS

Salinity tolerance experiments were conducted during the periods when the salinity of circulated seawater in the laboratory varied from 27 ppt to 32 ppt. During each of these experiments ten repetitive experiments were conducted. In each of the experiments a set of 11 beakers of one litre capacity were employed. The first beaker contained freshwater and second to eleventh contained seawater dilutions from 10 to 100%. The water content of each of these beakers was fertilised using the approximate combination of fertiliser so as to develop the bacteria and other microorganisms which constitute the food. In each of the beakers 10 parthenogenetic females of optimum size were introduced at the end of 24 hours of fertilisation activity in the water. Observations were continuously made for the period of 15 days, the period of mortality was recorded and average values have been presented in synoptic Table 1 common in regard to circulating seawater salinity of 27 ppt. 29 ppt. and 31 ppt. The water temperature throughout the experiments varied from 27°C to 29°C.

Experiments have been done only on upper lethal temperatures. The temperatures at which these die instantaneously was determined by taking hot water in finger bowls with a centigrade thermometer suspended by a stand. At a time, ten optimum sized parthenogenetic females were introduced in the temperature ranging from 50°C and downwards. The animals die instantaneously at 49°C.

Further observations on thermal tolerance were made by using the aquarium tank (70 cm × 70 cm). In this tank freshwater was taken. The electric appliances comprising thermostat and a heater were placed in a series circuit. Thermostat was suspended in the water, the range of sensitivity of the thermostat was ± 0.5° C. The thermostatic switch comprising the bimetallic strip was sealed to the lower limb of the 'L' shaped corning glass tube. The temperature was increased and decreased by turning the small screw attached to the bimetallic strip of the thermostat by using a long screw-driver (Shirgur and Kewalramani, 1973).

In each of these experiments ten optimum sized parthenogenetic females were taken in corning test tube with 10 ml of 11 ppt seawater which is optimum for the animal. Introduction of these animals was done only when the temperature within the experimental test tube was stabilized as that of the freshwater in the tank (akin to water bath). The time of initial introduction of the animals was noted down and the period required for total mortality was determined and the data is presented in Table 4. The data presented in these tables pertains to the accurate values determined in the final series of experiments using the jumo thermometer for accurate thermostatic controls. Average values of ten experiments in regard to each of the temperature level have been presented. The earlier experiments were conducted by 'L' shaped thermostat for pilot readings.

The principal organic fertiliser used for maintenance and proliferation of the animals has very remarkable characteristic reducing dissolved oxygen in the cultural media to lethal levels if used in higher doses (Shirgur, 1971).

Experiments were conducted first on solubility of the oil cake material upto saturation level. The saturated solution of oil cake in distilled water, taking as much as 10 grams of oil cake per litre of water (Naik and Shirgur, 1980 a). Shirgur (1971) has reported that 0.1 gm of oil cake solution per litre is the upper limit not to cause oxygen deficiency in regard to dissolved oxygen in the water being used as cultural media.

The standard solution in the form of clear supernatent liquid after complete precipitation of residue was taken as fertiliser solution. 50 ml of this solution was weighed and the weight was noted down. Similarly, the weight of 50 ml of distilled water was also noted. The difference in weight gave the solute per 50 ml of water. With this initial data, experiments were undertaken to find out safe processess of fertilisation per litre of cultured water per 24 hours under the water temperature range of 27°C-29°C.

One ml of this liquid per litre of cultured water was, therefore, optimum without causing any mortality even when the incamera water temperature was 31°C.

Observations

Table 1 presents very interesting data and significant behavioural features of *Alona* are noted in various salinity grades. In the salinity range of 34 ‰ to 27 ‰ downwards the tolerance period has been around 5 to 30 minutes, showing that these grades are totally hostile. The tolerance capacity thereafter suddenly increases with a threshold between 27 ‰ and 26 ‰, thus in the salinity range from 26 ppt to 23.4 ppt downwards the survival is in the range of 18 to 40 hours only. Then a second threshold is noticed between 23.4 and 21 ppt salinity. From 21 ppt downwards upto 17 ppt the survival period is in the range of 7 to 12 days. This shows a gradual tolerance capacity in the

TABLE 1. *Tolerance to salinity grades (Three stocks of seawater of different salinities)*

Sea water dilution	Number of *Alona* introduced	Survival time
34.0	10	5 minutes
30.6	10	10 ,,
30.0	10	15 ,,
27.2	10	30 ,,
27.0	10	30 ,,
26.0	10	18 hours
24.0	10	20 ,,
23.8	10	18 ,,
23.4	10	40 ,,
21.0	10	7 days
20.8	10	7 ,,
20.4	10	9 ,,
18.2	10	9 ,,
18.0	10	10 ,,
17.0	10	12 ,,
15.6	10	17 ,,
15.0	10	18 ,,
13.6	10	20 ,,
13.0	10	23 ,,
12.0	10	25 ,,
10.4	10	23 days and thereafter
10.2	10	25 days onwards
7.0	10	25 +
From 6 to freshwater	10	35 to 40 days.

survival periods increasing from one grade to another grade. There is another threshold between 17 and 15.6 ppt in the further downward salinity from 15.6 to 13 ppt salinity the survival is in the range of 17 to 23 days. This reveals yet another threshold between 13 and 12 ppt, from 12 ppt, from 12 ppt downwards these survive continuously with optimum life functions upto the salinity around 7 ppt. The lower salinity range from 7 ppt downwards upto pure freshwater despite provision of food and tolerable range of water temperature from day to day, the animals show poor rate of proliferation and from salinity 2‰ downwards the environment becomes again hostile with gradual mortality of culture within the protracted period of 35 to 40 days. Table 2 gives further details of experiments as to which of the tolerable salinity grades 40% downwards is to be regarded as optimum. Here the criterion for determination of optimum salinity was laid down on the basis of rate of proliferation of these animals under identical conditions of temperature, fertilisation and indirectly the dissolved oxygen position. Rate of proliferation has been observed for salinity grades from 22 ppt to freshwater when in each of these media initially ten adult females of the same age group and batch from the stock were introduced. It can be seen in Table 2 that these proliferation experiments have been conducted

TABLE 2. *Experiments for determination of optimum salinities on the basis at values of proliferation of* A. taraporevalae

Salinity of seawater	Number of *Alona*	*Alona* per litre
21 ppt	10	200
18 ppt	10	300
15 ppt	10	300
12 ppt	10	600
9 ppt	10	500
6 ppt	10	500
3 ppt	10	300
Freshwater	10	400

Salinity of circulating seawater 30‰
Water temperature 29°C

in regard to certain salinities above 40% and below 40%. It is very interesting to know from the results that even though the animals are not surviving continuously in salinity above 12 ppt these show proliferation to some extent reaching 300 per litre in 18 ppt and 200 per litre upto 21 ppt. The maximum proliferation has been observed in 12 ppt followed by 9 ppt and 6 ppt whereas in 3 ppt results are identical as in 15 ppt and 18 ppt. It is very significant to note that in freshwater there is spurt proliferation in upward direction giving as much as 400 organisms per litre.

Table 3 gives an account of salinity of the media for maintaining the stock of experimental animals, salinity of the media in which these were tested for gain of tolerance and remarks. The temperature range during these experiments was varying between 28.5°C to 29 °C.

TABLE 3. *Salinity of circulating seawater was* 31.3‰ *and temperature range* 28.5°C *to* 29°C

Salinity media for maintaining the stock animal (%)	Salinity media in which these were tested (%)	Remarks
8	24	Dead in 24 hours
8	26	Dead in 24 hours
14	24	Survived for one month
14	26	Survived for one month

Second series

Salinity from which animals were introduced (%)	Sea water (%)	24 hours	48 hours	72 hours
22	35.5	Alive	Alive	Dead
17	35.5	Alive	Alive	Dead
11	35.5	Alive	Dead	Dead
Fresh water	35.5	Alive	Dead	Dead

It can be seen from the tables that animals reared in 8 ppt survive within 24 hours in 24 to 26 ppt media. In the next series of experiments the animals reared in 14 ppt were introduced in salinity media of 24 ppt and 26 ppt and it was very significant to note that in these higher salinities, the survival was lengthened upto a maximum period of one month.

In the third series of observations the animals were taken from their original rearing media of freshwater, 11 ppt, 17 ppt and 22 ppt, and these were directly introduced in 35.5 ppt media. The animals lived in all four media whereas mortality occurred in case of fresh, 11 ppt within 48 hours. Contrary to this, the animals reared in 17 ppt and 22 ppt salinity survived upto 48 hours in 35 ppt media. It is very interesting to note that even these which survive for 48 hours cannot be prolonged beyond 72 hours survival. In order to rear the animals at 17 ppt and 22 ppt grades step by step increase in tolerance capacity was achieved by prior rearing in lower salinities.

From the above experiments it can be seen that the *Alona* reared in optimum salinity range of 10 to 12 ppt may be acclimatized from any of the required higher grades of salinities for feeding purpose.

Thermal tolerance of parthenogenetic females

From data given in the above Table 4 it can be seen that in the uppermost lethal limit the lowest temperature causative for instantaneous mortality was recorded at 49°C. At 48°C, the animal lived only for 40 seconds. After this temperature level, a definite threshold is observed wherein the survival crossed above one minute period from 47°C downwards and within the range of 47°- 44°C these survive for maximum of 15 minutes, that is within one hour. A third threshold occurs between 44°C-43°C. At the temperature 42°C the animals lived for five hours indicating thereby very high tolerance. At the temperature between 42°C-39°C *Alona taraporevalae* lived upto maximum 19 hours thereby showing a fourth threshold between 39°C and 38°C.

In 38°C these lived for 2 days again showing a high tolerance capacity at this temperature. In the temperature range of 33°C these lived upto maximum of 8 days. A fifth threshold is thus indicated between 33°C and 32°C. From 32°C downwards although these live indefinitely, but the rate of proliferation is considerably low. In this respect from 30°C onwards besides surviving indefinitely the *Alona*

TABLE 4. *Survival periods in seconds, minutes and hours in case of* Alona taraporevalae *from temperature (in centigrade) of instantaneous mortality to continuous normal survival*

	Serial number	Temperature (°C) tried	Survival period
	1	49 (Lowest temperature to cause instantaneous mortality)	
Threshold 1	2	48	40 seconds
Threshold 2	3	47	1 minute
	4	46	2 minutes
	5	45	5 minutes
	6	44	15 minutes
Threshold 3	7	43	1 hour, 20 minutes
	8	42	5 hours
	9	41	8 hours
	10	40	15 hours
	11	39	19 hours
Threshold 4	12	38	2 days
	13	37	3 days
	14	36	3 days
	15	35	4 days
	16	34	4 days
	17	33	8 days/does not reproduce
Threshold 5	18	32	15 days
Threshold 6	19	31	Continuous

show a normal pattern of reproduction. Thus for optimum cultural temperature, the cultural media may be preferably maintained at the maximum of 30°C.

Minute observations on salinity grades of 50% (15‰) downwards have revealed that under lower water temperatures the animals tend to live continuously in higher salinities like 50% and above. This tends to reveal that lower the water temperature, higher is the capacity to tolerate slightly upper levels of salinities in which these normally die off at higher temperature. Thus water temp ratures below 31°C upto 27°C are to be taken as optimum in a broad range.

D.O. requirement

Fig. 1 gives the details of contours of respiratory surfaces. The areas in which the haemolymph is oxidised and the surrounding liquid is reduced take up the stain and become sharply distinguished from the adjacent surfaces. This procedure shows the gills which are situated on the posterior margin of the outer side of the legs. A small area around the main head pores is also clearly stained. As can be seen from Fig. 1 the processes on the opipodites are not very clear indicating thereby a sort of similarity as that of pelagic daphnidae mentioned above. It seems that lack of processes on the epipodities in *A. taraporevalae* indicates its planktonic nature and occurrence in the surface columns which is normally rich in D.O. level.

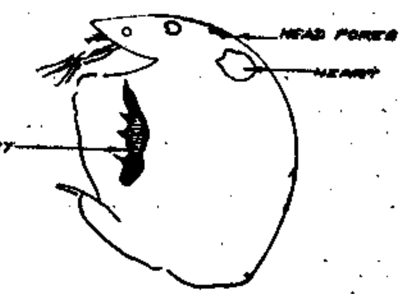

Fig. 1. *Alona taraporevalae* Shirgur and Naik: Respiratory surfaces stained ($KMnO_4$) and magnified (10X) X 10.3.

Considering the above clue it was, therefore, imperative to undertake studies on D.O. requirement in relation to progressively increasing doses of fertilisation especially increase in the organic ones. Table 5 gives the data of average values about D.O. level in ppm in one litre cultural beakers numbering ten containing optimum seawater media around

TABLE 5. *Average D.O. values (in ppm) in optimum salinity media of* 11 ‰ *in relation to maximum proliferation*

A.	Ground nut oil cake concentration at 1 ml ..	1 gm of oil cake yields 200 mg of soluble part						
		24 hrs	48 hrs	72 hrs	96 hrs	120 hrs	144 hrs	168 hrs
	Dissolved oxygen ..	6.2	5.8	3.6	3.8	4.5	6.3	6.6
	Number of organisms ..	Maximum number obtained 300/litre						
B.	Ground nut oil cake concentration at 2 ml ..	24 hrs	48 hrs	72 hrs	96 hrs	120 hrs	144 hrs	168 hrs
	Dissolved oxygen ..	3.4	3.0	1.5	1.6	2.0	3.2	3.0
	Number of organisms ..	Maximum number obtained 140/litre						
C.	Ground nut oil cake concentration at 3 ml ..	24 hrs	48 hrs	72 hrs	96 hrs	120 hrs	144 hrs	168 hrs
	Dissolved oxygen ..	0.9	0.2	0.8	0.8	0.3	0.2	1.0
	Number of organisms ..	Almost no animals.						

11 ppt. In this set (A) the fertilisation was done at the rate of 1 ml of the ground nut oil cake solution per litre. The reading of the oxygen level was taken by Winkler's method and the average values are recorded. Initially in each of the beakers 10 animals were introduced and the number proliferated at the end of one week period was nearly 300 per litre. The oxygen which was initially around 6.2 ppm was gradually reduced to 3.6 and 3.8 ppm by the middle of the week. The D.O. level again started rising reverting to the level by the end of week as was the case initially.

In the second set of experiments (B) 2 ml of the ground nut oil cake solution was administered one day in advance as in the case of experiments of 'A' series. The oxygen level within 24 hours of fertilisation action was only 3.4 ppm and was reduced to only 1.5 to 1.6 ppm by middle of the week and the D.O. position again showed almost similar to initial level. Proliferation rate of *Alona* was slow and around 140 animals were formed at the end of the week.

In the third set of experiments (C) the oxygen level at the end of 24 hours of fertilisation activity at the rate of 3 ml per litre was only 0.9 ppm and which was abruptly lowered to 0.2 ppm at the end of 48 hours and at the end of 72 and 96 hours, it gradually rose only to be reduced at the end of 144 hours. At the end of one week it was only 1.0 ppm. The organisms introduced could not survive beyond 8 to 10 hours and total mortality occurred. The cultural water was foul smelling.

It can be seen from the above experiments that 1 ml of oil cake solution per litre of cultural water is desirable, which yields around 18 m. gms of soluble portion. The oxygen level was never reduced beyond 3.6 ppm showing that the proliferating animals are tolerant at this level. Besides, the rate of proliferation was also satisfactory reaching to nearly 300 per litre at the end of one week. On continuation of culture beyond 1 week, the proliferated animals reached the maximum of nearly 600/700 per litre.

During the above experiments the temperature varied from 28°C-30°C. It is thus clear that for better results the frequency of fertilisation at the end of 1 ml of oil cake solution per litre on every alternate day would be preferable.

Similar experiments have been reported (Shirgur, 1971) in case of *Moina* sps. (freshwater forms).

Discussion

As can be seen from the above results the optimum range of salinity has been 10 ppt to 12 ppt. This finding was derived on the basis of important experiments on comparative rates of proliferation of *Alona* in different salinity media and corroborated by the experimental results to understand percentage of ephippial females in various salinity media. It is very interesting to note that not only the numbers proliferated is maximum being 600 per litre in the optimum range of salinity media, but also these media very interestingly do not favour formation of sexual females (Naik and Shirgur, 1980 c). This seems to be due to perfect harmony of life processes under optimal conditions. Observations have also been made on gain of salinity tolerance which information becomes very useful in feeding of these food organisms for seed production of economically important prawns and fishes in higher salinity media.

From the above experiments it can be seen that whenever the *Alona* are to be fed to nurse the hatching of commercially important prawns and fishes in the salinity than the optimum salinity of these food organisms, to ensure survival until ingested by the feeding animals step by step acclimatisation can be tried. Thus, the *Alona* reared in optimum salinity range of 10 to 12 ppt may be acclimatised for any of the required but suitable higher grades of salinity for feeding purpose.

In regard to thermal tolerance 49°C is the lowest temperature of instantaneous mortality. Further trials to tolerance to consecutively lower temperatures revealed six thresholds of tolerance behaviour. The first threshold is between 49°C and 48°C, the second is between 48°C and 47°C, the third is between 44°C and 43°C, the fourth is between 39°C and 38°C, the fifth is between 33°C and 32°C, the sixth is between 31°C and 30°C. From 30°C onwards these produce normally.

The results with reference to dissolved oxygen requirement have shown that oxygen level below 3.8 ppt are not conducive for normal rate of proliferation. The fertilisation in relation to this parameter was, therefore, 1 ml per litre at 48 hours interval. If the proliferated animals are not netted out for use, the rate of fertilisation although remains same may have to be done at greater intervals than 48 hours, because the net output in the form of proliferated animals is practically unutilised and the resources in general remain in the cultural waters and are subjected to cyclic variations.

In regard to observations on D.O. requirements it was found that these could tolerate the D.O. level from 3.8 ppm and above the safe level of periodical fertilisation (48 hours interval) is 1 ml of ground nut oil cake solution per 1 litre of cultural waters.

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OBSERVATIONS ON REPRODUCTIVE BIOLOGY OF A BRACKISHWATER CLADOCERAN *ALONA TARAPOREVALAE* SHIRGUR AND NAIK

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ABSTRACT

This paper presents details on reproductive behaviour of *Alona taraporevalae* Asha Naik and Shirgur.

In sexual dimorphism, male is relatively smaller than the female with respective average sizes of 0.3 and 0.5 mm. Besides, the male has morphological specialisation in the first leg with recurved hook that facilitates copulation. Parthenogenetic females constitute the majority in the culture, wherein these reproduce normally by parthenogenesis, and under certain adverse conditions, the sequence of parthenogenetic batches bearing young ones, becomes interrupted by only one sexual batch. Parthenogenetic eggs on introduction into the brood chamber develop into fully formed hatchlings similar in morphology as that of the adults, within 24-30 hours. There are only 2 in stars of the young ones preceding the third which is normally capable of parthenogenetic reproduction. During the whole life span of an individual on an average, 9-11 moultings take place and in all 15 batches of the young ones are produced. In a sequence during the reproductive phase, within the range of 6-8th batch, sexual batch is normally interpolated. Considering the overall fecundity during the entire life span, an individual, on an average, produces 29-30 young ones. Parthenogenetic batch comprises two hatchlings as against only one in sexual batch. Life span of an individual, on an average, is of 30-32 days.

Observations on appearance of sexual forms bearing ephippia have shown that except in the optimal range of salinity around 10-12 ppt in all the other media, higher and lower, nearly 20-40% sexual females occur during the peak level of population.

INTRODUCTION

IN THE PREVIOUS work (Shirgur and Naik, 1977) salient features of reproductive behaviour of *A. taraporevalae*, a chydorid brackishwater cladoceran, have not been made except for few observations on morphology of parthenogenetic male, parthenogenetic female, sexual female and males and ephippial hatching.

In the present paper various aspects studied are as outlined below.

a. Sexual dimorphism.

b. Copulation and production of resting egg, structure of ephippia and size of egg within ephippia.

c. Gametogenesis in case of parthenogenetic female, duration from egg to hatchling stage (embryonic stage), nature of parthenogenetic eggs.

d. Stages comprising the instars, upto the phase of formation of reproductive adult (maturation).

e. Life span from egg to adult until mortality due to natural reasons of salinity, behaviour of adult and observation of total number of clutches

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produced in the whole span of an individual, number of young per clutch.

f. Fecundity.

Smirnov (1974) has given an account of ephippial formation in different chydorids and the morphological features of ephippia in general.

Very little information is so far available as regards the causative factors of ephippial formation. According to Smirnov (1974) the only reason so far given in adverse conditions which of course are not well defined. In the present studies, observations have been made about the populations maintained in different salinity media to find out whether salinity is the chief factor for ephippial formation. Further studies have been made on correlation of duration of dessication, duration of soaking and hatchability of ephippia.

We take this opportunity to express our thanks to Dr. M. R. Ranade, Marine Biological Research Station, Ratnagiri for his constant encouragement in this work. We are also thankful to the authorities of the Council of Scientific and Industrial Research for granting the necessary Junior Research Fellowship to Shrimati Naik during the years 1975-1979.

Material and Methods

The culture of the animals required for this study was initiated by taking the ephippia of two years' storage. The hatching occurred within 30 days (Shirgur and Naik, 1977; Naik and Shirgur, 1980 a).

Initial studies on growth leading to maturation were made by taking the newly hatched animals in the cavity blocks. Microscopic observations were made on each of the successive instars and the records were made as to which instar matures and gives rise to the first clutch of young ones in parthenogenetic phase. Gonadial observations were made under microscope and camera lucida drawings were made and photographed. The reproductive behaviour of parthenogenetic females was observed by keeping the newly hatched young in the cavity block containing the fertilised media. Observations were continuously made on number of clutches during the life span of each of the animals observed. The data of these experiments was analysed to determine fecundity under the optimum conditions of salinity, temperature and dissolved oxygen levels related to fertilisers. Observations were also made on ephippial formation and hatching. Out of the many cavity block observations containing parthenogenetic females only on two occasions ephippia were produced at 6th and 8th clutches, respectively.

As regards ephippial hatching the ephippia lying on the bottom of cultural beakers were recovered and dried. The approximate date of obtaining the ephippia was noted down. Then the experiments were conducted for hatching on the dry stored ephippia of various durations of storage.

Observations

Sexual dimorphism

It was observed that during the sexual phase the parthenogenetic females get themselves transformed into sexual females during their respective individual life span, and after moulting along with the ephippium these revert to parthenogenetic phase. In pace with formation of sexual female the males are also produced by the parthenogenetic females. Males are smaller than females (0.3 mm as compared with normal size of female 0.5 mm on an average), Fig. 1a and b. The male has a narrow post abdomen and uses the hooks of leg I so that the apex of the hook is situated below the margin of the valve of the female. The hook of the first leg is relatively variant morphologically as that of the female in that it is for specific functional facility. Smirnov (1974) has given an account of sexual dimorphism and other features about chydoridae.

Formation of resting eggs

Fertilisation involves in the introduction of markedly modified postabdomen of male below the valve of the female. The males of *A. taraporevalae* were found to be discrete within the cultural media, these seem to attach to the female only for a brief duration; after copulation these detach and continue to live freely. Fertilisation results in the formation of resting eggs in an ephippium. Each ephippium contains only one resting egg. The ephippium is discharged along with the moult and the female resumes its sequential activity of production of parthenogenetic eggs. The ephippium is dark brown and opaque measuring around 0.34 mm. The ephippium normally sinks to the bottom. Under normal conditions the freshly laid ephippium submerged in the cultural water takes ten days for hatching. During hatching process the bivalve of the ephippium opens and from within emerges a capsule of transparent membrane. This capsule encloses a fully formed hatchling which on tearing the membrane emerges out (Fig. 1 c). The hatchling from the ephippium develops in to parthenogenetic female.

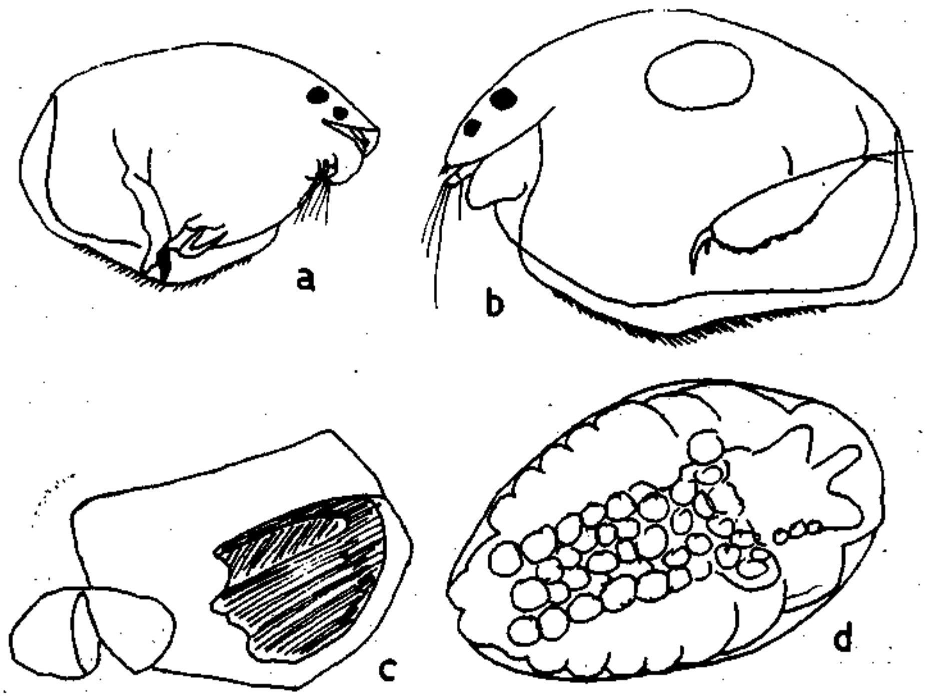

Fig. 1. *Alona taraporevalae* Shirgur and Naik : a. male (body length 0.392 mm); b. Parthenogenetic female (body length 0.4710 mm); c. Ephippia with an empty membrane torn due to release of hatching and d. early embryonic stage of a parthenogenetic egg within the brood sac.

Gametogenesis in case of parthenogenetic female

The parthenogenetic females were kept individually in respective cavity blocks for observation under microscope. The ovaries were seen developing on the lateral side ventral to the intestine in the thoracic region of the body. Eggs are passed through the transparent oviduct into the brood chamber. The eggs are oval in shape, yellowish in colour and undergo a series of embryonic division (Fig. 1 d). In the early stages the egg is granular ; then the peripheral region becomes clear. It develops limb buds and then the ocellus and eye is also formed. The heart is seen beating. The embryo remains inside the brood pouch of the mother till it is capable of swimming freely. As regards embryonic stage it was observed that parthenogenetic egg from time of its release in the brood chamber upto the time of the release of fully formed young one is 24-30 hours.

From hatching to first reproductive adult phase the total period taken is nearly of 48 hours. Considering the hatchling as first instar, two more instars are preceded to the one which is the reproductive adult. Thus, there are two moults until the first reproductive instar is formed.

Nearly 15 parthenogenetic females have been observed individually starting from hatchling stage upto the time of their natural mortality in their respective cavity blocks. It was observed that on an average the life span of an individual varied between 30-32 days and the total number of moults were 9 to 11 during the entire life span.

During the entire life span nearly 15 batches of young ones are produced in a series. It is very interesting to note that during the succession of parthenogenetic batches interspersed at 6th to 8th is a sexual batch. The sexual egg is formed within the ephippium.

It is thus observed that nearly after completion of half the life span there is a tendency to produce sexually only once, after this sexual phase there is reversion to normal succession of parthenogenetic batches. Each parthenogenetic batch gives rise to only two young ones as against only one produced from an ephippium.

Fecundity

Fecundity is the index of number of young produced during the life span of an individual (Lowe, 1955). On the basis of the details given above it can be seen that through nearly 15 batches comprising only one sexual and rest parthenogenetic, an individual gives rise to total of nearly 29-30 young ones.

Smirnov (1974) states that although chydoridae show low fertility they may have high density. The density of *Eurycercus lamellatus* does not exceed 60,000 organisms per cubic meter in nature or in culture as against *Saycia cookii* which produces numerous eggs which are extremely rare. The maximum density of chydorinae is about 10,00,000 per cubic meter in nature and in cultures. In the present study the artificial culture of *Alona taraporevalae* has given six lakh organisms per cubic meter. The occurrence and density under natural conditions is yet to be studied.

Ephippial formation, percentage of males and females in cultural media and hatchability of ephippia

Conditions causative for ephippial formation in the cultural media of different salinities constitute very important considerations for initiation of cultural work. Smirnov (1974) has given an account of ephippial formation in different chydorids and the morphological features of ephippia in general. The chydorid population having single period of bisexual reproduction are termed monocyclic. *Alona taraporevalae* is dicyclic because throughout the year there are two population maxima wherein the population consists of sexual females and males. The first period is around August and September and second is around February and March. The dicyclic pattern becomes evident only when the cultural beakers are well maintained.

It is very significant to note that if there are slight variations in cultural conditions the cultural beakers of different salinities comprise the populations which show polycyclic pattern. Thus, the ephippial females appear all round the year.

Table 1 presents data on percentage of ephippial females within the population in one litre beakers at various salinity grades. It can be seen from this table that in the salinity media 12 ppt, 11 ppt and 10 ppt. when properly maintained there was no formation of ephippial females, except in case of salinity media 12‰ wherein 20% of the females were ephippia bearing after 15 days' period.

TABLE 1. *Percentage of ephippial females in the population of cultural beakers*

Water temperature (°C)	Salinity media (‰)	Percentage of ephippial females to the total population
29	12, 11, 10	No ephippia formed in these three salinities. Ephippia appear only in 12‰ after 15 days. 20% ephippial females.
	9	After one week—30% ephippial females.
	8, 7, 6, 5, 3	After one week—40% ephippial females.
	Freshwater	After one week—30% ephippial females.

In salinity media 9‰ after one week's period there were 30% ephippia bearing females indicating this medium to be more adverse than that of 12‰. In salinity media 8‰, 7‰, 6‰, 5‰ and 3‰ after one week the population consisted of 40% ephippia bearing females, showing that these media are not natural to this species. In fresh water media 30% ephippia bearing females were observed, again proving this medium to be unnatural. During the above experiments the water temperature varied around 28°C to 27°C.

From the above analysis a very important clue has become evident showing that salinity media of 10‰ and 11‰ are the most optimum which inherently do not cause ephippial formation in *Alona taraporevalae* populations. There is a corroboration for this clue by the experiments as comparative rate of proliferation in different salinity media. Naturally, the population maxima of around 600 per litre was observed in 10‰ and 11‰ media.

Some observations have also been made on percentage of males to females comprising both parthenogenetic and sexual females. The data given in Table 2 shows that in two different sets of beakers of 8‰ media, 9% and 19% were the proportions of males to females in general. These observations were made after cultural duration of 8 days. This reveals that 10% to 20% approximately are males in these populations. In the third instance the cultural beaker of 8‰ nedia when sampled after 14 days showed 8% of males, thereby showing some decline. The above results tend to indicate in general that when the ephippial females are around 20% to 40% of the total population the proportion of males occurs around 10% to 20% (Tables 1 and 2). Thus the population of males is in the range of 25% to 50% to that of the population of sexual females.

TABLE 2. *Percentage of females and males in population of 8‰ media*

Total number sampled	Percentage of	
	females	males
11	82	18
16	93	7
26	88	12
20	95	5
17	100	0
16	100	0
51	98	2
12	83	17
22	91	9 In 8 days
22	81	19
20	92	8 After 14 days.

Correlation of duration of dessication, duration of soaking and hatchability of ephippia

Table 3 presents data comprising the above features.

In the second week of August, 1973, an examination of seawater samples from the Back Bay showed a few ephippia resembling those of a freshwater form, *Moina sp.* They were put in salinity media respectively of 4, 8 and 12‰ and ranging upto 26‰ as the natural seawater from which these were obtained was of salinity around 26‰.

The hatching took place at the end of 18 days in 8‰ and 12‰ media under temperature around 27-28°C. The culture techniques for these organisms were the same as reported earlier (Shirgur, 1971 ; Shirgur and Naik, 1977).

As the culture progressed the ephippia obtained were dessicated and stored in plastic tubes. It can be seen from Table 3 that the ephippial hatching experiment was carried out by using the ephippia which when stored for two years but were subjected to hatching in the year 1975. The third, fourth and fifth experiments were carried out by using the ephippia obtained in 1975 and 1976 from animals produced by second experimental hatching.

In these experiments the effects of the variables such as the salinity of the culture media of recovering the ephippia, subsequent different storage periods, different salinity and temperatures ranges for hatching, were observed.

The ephippia collected from seawater under natural conditions were intact and undamaged although become soft and pliable due to prolonged immersion. When these were subjected to varying salinities, hatching occurred only in low salinities ranging from 8 to 12‰, at the end of 18 days, indicating that the higher salinities were not suitble for hatching and proliferation. It lends to a conjecture that this species probably thrives under estuarine conditions. The second experiment using two year old ephippia gave first hatching in 12‰ media around 27-28°C and hatching took place after 40 days, indicating that prolonged storage tends to retard hatching.

The third experiment has shown that the ephippia obtained from very low salinity media around 2‰ and stored for 1.5 weeks gave hatching within two or three weeks at temperature around 28-29°C. This experiment revealed a very interesting feature that ephippia from very low salinity culture media also suffer retardation in hatching period.

The fourth experiment using ephippia from cultural media of 12‰ salinity and storage period of 24 weeks gave quick hatching in all media ranging from 2-26% and around temperature 28-29°C.

The last experiment using ephippia obtained from culture media of differnet salinities, with six weeks of storage time, gave thatching within six days at the same temperature at 12‰ hatching media.

The last three experiments indicate that storage for a minimum of 6 to 24 weeks would give hatching within a short period.

Table 4 gives an account of ephippial hatching for the further periods starting from April, 1976. As can be seen from the above Table 4, 10 experiments giving average values had been conducted on different patterns as compared with those presented in Table 3. In all the new experiments the ephippia collected from various salinity media have been hatched in respective salinity media only unlike the previous series of experiments. In case of first experiment the ephippia of 5 weeks' storage were collected from 6‰ media and hatched in the same media in 4 days. The experiments 2-5 are concerned with the ephippia collected from 8‰ media for different durations of

TABLE 3. *Results of experiments on hatching of ephippia of* Alona taraporevalae

Date of collection of Ephippia	Salinity (‰) media from which ephippia were collected	Duration of storage of ephippia	Date of introduction of ephippia for hatching	Salinity media for hatching (‰)	Temperature range during hatching period (°C)	Date of hatching	Duration of incubation
16th August 1973	Few ephippia obtained from seawater of salinity 26‰ from Back Bay off the Institute	Not possible to ascertain	16th August 1975	8 and 12	27-28	3rd September 1975	18 days
5th September 1973 from Laboratory culture	Mainly around 12‰	Two years	20th August 1975	12	27-28	29th September 1975	40 days
29th March 1976 from Laboratory culture	From 2‰ water	1 week 3 days	8th April 1976	8 10	28-29	20th April 1976 27th April 1976	12 days 19 days
28th October 1975 from Laboratory culture	From 12‰ water	24 weeks	22nd April 1976	2, 4, 6, 8, 10, 12, 14, 15, 16	28-29	27th April 1976	In all media in 5 days
25th July 1976 from Laboratory culture	From fresh-water, 1.5, 2.5, 4.0, 7.0 and 8.0‰	6 weeks	8th September 1976	12	28-29	14th September 1976	6 days

TABLE 4. *Results of experiments on hatching of ephippia of* Alona taraporevalae

Date of collection of ephippia		Cultural salinity (‰) media from which ephippia were collected	Duration of storage of ephippia	Date of introduction of ephippia	Salinity (‰) media for hatching	Temperature range during hatching period (°C)	Date of hatching	Duration of hatching
28th March 1978	..	6	5 weeks	4th May 1978	6	30	8th May 1978	4 days
10th June 1977	..	8	8 weeks	12th August 1977	8	28-28.5	16th August 1977	4 days
29th July 1977	..	8	2 weeks	12th August 1977	8	28-28.5	16th August 1977	4 days
18th March 1978	..	8 autoclaved water	2 weeks 3 days	6th April 1978	8	28.5	9th April 1978	3 days
28th March 1978	..	8	1 week 2 days	6th April 1978	8	28.5	12th April 1978	6 days
25th July 1977	..	10	2 weeks 4 days	12th August 1977	10	28-28.5	3rd September 1977	21 days
6th April 1976	..	Freshwater	Wet ephippia	6th April 1976	Freshwater	27-28	12th April 1976	6 days single hatched
12th July 1977	..	14	4 weeks	12th August 1977	14	28	16th August 1977	4 days
19th April 1978	..	17	2 weeks	4th May 1978	17	30	8th May 1978	4 days
5th September 1977	..	17	6 months	23rd March 1978	17	26	30th March 1978	7 days

storage were hatched in the respective media only. It is observed that the ephippia starting from one week and two days storage period upto the maximum of 8 weeks storage period gave hatching within 4 days except in case wherein six days were required for hatching. In experiment No. 6, the ephippia of 2 weeks and 4 days storage hatched within 21 days. In case of fresh-water the wet ephippia hatched in 6 days. In case of 14‰ four weeks old ephippia hatched within 4 days. In case of experiments 9 and 10 for the common salinity of 17‰ two weeks old ephippia hatched within 4 days as against 7 days taken for six months old ephippia. In case of the latter experiments, the water temperature was only 26°C during hatching operation. This, perhaps, shows the favourable effect of lower temperature in case of hatching at higher salinities and consequently in case of the six months' old ephippia hatching period was not correspondingly advanced.

From the above experiments it can be seen that the shorter period of nearly 4 to 6 days was required for hatching in case of ephippia stored not beyond 8 weeks. Longer the duration of ephippial storage the hatching period is also likely to become correspondingly longer. One more significant point in these sets of experiments is probably the overall duration of hatching period which is in the range of 4 to 7 days. This may be due to common salinity media for ephippial collection and hatching.

Discussion

On summarising the important features it can be seen that (1) optimum range of salinity has been 10 to 12‰ (Naik and Shirgur, 1980 b). This finding was derived on the basis of important experiments on comparative rates of proliferation of different salinity media and corroborated by the experimental results to understand percentage of ephippial females in various salinity media. It is very interesting to note that not only the numbers proliferated is maximum being 600 per litre in the optimum range of salinity media but also these media very interestingly do not favour formation of sexual females. This seems to be due to perfect harmony of life process under optimal conditions.

In regard to reproductive behaviour, the following are important general features (1) Sexual dimorphism concerning the male is marked by comprising recurved hook which facilitates copulation, (2) parthenogenetic females constitute the majority in the culture which reproduce normally by parthenogenetic batches producing young ones interpolated by only one sexual hatch, (3) parthenogenetic eggs on introduction into the brood chamber develop into fully formed hatchlings being morphologically similar to the adults within 24 to 30 hours, when these are released from the brood chamber, (4) there are only two instars of young ones preceding the third which is capable of producing parthenogenetically, (5) during the whole life span 9 to 11 moultings take place, (6) during the whole life span there are nearly 15 batches of young ones, (7) during 6th to 8th batches sexual phase is normally interpolated, (8) considering the overall facundity 29-30 young ones are generated during the entire life span of one individual, (9) parthenogenetic batch comprises two hatchlings as against one as in sexual batch, (10) the life span of an individual of average size is 30 to 32 days.

Observations on ephippial formation in the cultural beakers have revealed that except in the optimal range of salinity, in the other media higher and lower, nearly 20 to 40% sexual females appear during the peak level of population. Percentage of males in the population is around 25 to 50% as that of the sexual females.

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TRAINED MANPOWER FOR COASTAL AQUACULTURE

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ABSTRACT

For the organised development of fisheries as a whole the availability of property trained manpower is a pre-requisite. Coastal aquaculture, which is a new phase of development, has acquired importance only very recently in this country and therefore the manpower needed for the programmes requires careful planning. While fresh water-fish culture practices involving seed collection or production, nursery management, stocking, intensive/composite culture of different species, and even induced breeding, has made commendable progress in the last decade, the practice of shrimp culture, mussel and oyster farming etc., though developed at the laboratory and to some extent even at pilot scale levels, are still to become commercially feasible ventures. Aquaculture of prawns is a multi-disciplinary science drawing upon biology, marine biology, ecology, genetics, water and soil chemistry, biochemistry and microbiology; in addition, engineering aspects of construction of coastal farms which involve building dykes, sluices, and pollution control, need specialised personnel. Post-harvest technology of the shrimp may need special attention since the quality and properties of farmed fish and shrimp are known to be different from those of the wild stock obtained by normal sea fishing. The number of operatives who also have to be highly skilled for the process of rearing shrimp from the hatchery stage to the harvesting stage which involves very delicate adjustment of feeds etc. at the different growth stages will be very large. The training of all the scientific, technical and other personnel is a task of the Central Fisheries Institutes, the State Departments of Fisheries, and the Agricultural Universities. The above aspects are discussed in the paper.

COASTAL aquaculture is hailed as an alternative source of additional supply of fish since it has been realised that the marine fisheries resources are not unlimited and probably will not support more than twice the present annual production. The higher inputs required for deep sea distant water fishing is another consideration. Currently in India, aquaculture is receiving more attention mainly because of the need to fill the gap between the demand and supply of profitable exportable commodities such as prawns for the expanding overseas market. Besides prawns choice varieties of fish such as mullets, *chanos* (milkfish), *Etroplus suratensis*, *Lates calcalifer*, etc. could be cultivated through coastal and brackishwater aquaculture. Another promising field seems to be the culture of mussels, oysters and some species of seaweeds in coastal areas. While the exploitation of the fishery resources is the task of the industrial sector the provision of infrastructural facilities such as fishing harbours, procurement of ships, the training of technical manpower, provision of institutional finance for the enterprise, is essentially the responsibility of the government and semi-government agencies. The trained manpower needs of the country were examined thoroughly by the Fisheries Education Committee of the Government of India in 1959 and accordingly educational and training institutions such as the Central Institute of Fisheries Education, Bombay and the Central Institute of Fisheries, Nautical and Engineering Training, Cochin

* Deceased

and Madras, were established in the early sixties. Coastal aquaculture, which was then little thought of seriously, naturally did not find a special place in the training programmes visualised for these institutions. It is therefore necessary now to consider the specific needs of the trained manpower which is required for undertaking the coastal aquaculture programme on a large scale and also for transferring the existing knowhow to the field.

Like fishery science itself, aquaculture is a multidisciplinary science drawing upon various basic sciences such as marine biology, ecology, alogology, limnology, chemistry and physics of seawater, biochemistry and nutrition, and microbiology ; also, construction of sea walls, dykes and sluices for the fish farms need specialised engineering knowledge. Fisheries development has strong social objectives to fulfill in a developing country like ours and hence socio-economics are intimately linked with the development of coastal aquaculture. The training of manpower must take into account all these factors.

The personnel required in fisheries activities can be classified into (i) The primary sector consisting of all seagoing operations in marine fishing and the fish farm and fish culture operations in fresh water, brackishwater or coastal aquaculture ; (ii) Managerial/supervisory personnel ; (iii) Research workers and specialists and (iv) Extension workers. All these personnel require training, sometimes of a comprehensive character which can be imparted at only specialised institutions. Normally the level at which education is needed for the above different categories is considered at the Certificate/Diploma level for category (i) and the University Degree/Postgraduate Degree for category (ii) and category (iv) for category (iii) a Postgraduate Degree followed by at least 3-5 years of experience in the specialised field would be necessary. The above personnel are directly connected with the fishing activities ; there are persons in occupations which have a bearing on fisheries activities which need some awareness of fisheries problems and some provision for imparting knowledge to them also should be envisaged in any adequate programme of fisheries education.

Coastal aquaculture is comparable to the primary sector of the fishing industry such as the sea-going activities though the location is away from the usual fishing grounds ; the various techniques used in aquaculture and the different activities associated with it make it difficult to define qualifications of the aquaculturist adequately. In general, however, the fish culturist must have some knowledge of the life history and environmental conditions which are favourable to the species he wishes to raise, how it is to be raised to reach the marketable size most rapidly and cheaply, how to control the disease which can affect it ; he has to be partly biologist, partly chemist and engineer, and basically an animal husbandry man.

The knowledge which an aquaculturist basically requires includes physical and chemical conditions of brackishwater and seawater, the biological communities inhabiting the environment, particularly in the intertidal and subtidal zone, some aspects of soil science such as permeability and plasticity, density of soils in relation to the moisture content, mud and their properties, suitability of soil for fish culture ; engineering related to construction of ponds and dams ; in respect of fish culture he must have knowledge of the rate of growth of the species, their food habits, supplementary and natural foods, ways of feeding ; management of ponds, understanding of the rates of stocking, weed control, methods of cropping/harvesting ; seed collection from natural sources when available and seed production through induced breeding and proper hatchery management. In addition he must understand the economics of fish culture, and marketing of the product. There must be due awareness of the public health aspect, particularly the impact of pathogenic organisms such as *Salmonella*, the occurrence of which in the cultured prawns/fish could constitute health hazard to the public and also affect the export of the prawns, etc.

The categories of personnel required for coastal aquaculture can be summarised broadly as (i) The farm operatives who have to possess the necessary skill and experience inhandling the farm operations; (ii) Assistant Aquaculturists ; (iii) Aquaculturists, and (iv) Senior Aquaculturists. The farm operatives have to be trained through practical experience on the farms which are in actual operation. The Assistant Aquaculturists must be able to appreciate the principles of biological management ; their essential subjects of study are the same as that of the Aquaculturists and the Senior Aquaculturists, but the levels of knowledge expected is naturally different for the three different categories. For the Assistant Aquaculturist the Certificate of Proficiency would suffice and for the Aquaculturist the Diploma should be adequate ; for the Senior Aquaculturist the Degree level knowledge of the subjects in question is necessary. The Senior Aquaculturist must have a wide ranging biological background besides the capacity to understand chemistry, biochemistry, micro-biology, physics and statistics.

The Central Institute of Fisheries Education, Bombay has been conducting courses at the postgraduate, graduate Diploma, and at the Inland Fisheries Operatives levels for the past several years. Those who were trained in these courses could with additional training in aspects specific to coastal aquaculture practices be able to meet the requirements of the different categories of staff mentioned above. Besides the CIFE trained persons graduates from some of the agricultural Universities who have started courses in Fisheries could also be available for the special training in aquaculture. The Central Fisheries Research Institutes *viz.* the C.M.F.R.I. and the C.I.F.R.I. could provide the specialist cadre of personnel required for the aquaculture operations.

For persons who have already undergone some training in fisheries relatively short course of 6 months to 1 year might suffice to equip them with sufficient knowledge for aquaculture activities ; for those who have had no previous training a longer course, possibly a two year course after graduation in science having biology as one of the subjects would be needed. The ICAR Fisheries Research and Educational Institutes could conduct such a course besides short term courses drawing upon the expertise and facilities available at the various centres under the ICAR research institutes. It has been the experience that if research institutes are directly involved in training activities it could only be at the cost of some deterioration/distraction from their essential activity *i.e.* research.

In planning the short term and long term training courses in coastal aquaculture it is necessary to see that criticism levelled at several of our technical courses that the syllabi prescribed do not take into account the exact job requirements, are not justified. In spite of the fact that there are Governmental and University institutions conducting various fisheries courses the fishing industry suffers from an acute shortage of suitable personnel. A major feature of the fishing and processing industry in India is that at present it is depending entirely on the export market for its very existence, because there is no organised domestic market for our processed fish products. A strong domestic base is necessary for the stabilisation of the industry. The development of coastal aquaculture might cater essentially to the export market by emphasizing the production of exportable species such as prawns in the initial stages, but it must consider developing a domestic market for its produce ultimately. Probably it would be necessary to associate the fishing and processing industry actively with the framing of the course content, methods of training, etc. at the planning stage itself. Unless the industry can employ the trained persons particularly at the degree and higher levels, the purpose of the training imparted will not be served.

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PROSPECTS OF CROP-LIVESTOCK-FISH INTEGRATED FARMING SYSTEM IN INDIA

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ABSTRACT

The ever increasing population of the world and its demand for protein rich food has become problem/challenge to the mankind. In order to meet this challenge, scientists are busy in exploring the possibilities of synthesising better protein chains, developing new sectors/ methods systems and techniques, whether it be from plant origin, animal origin or through chemical synthesis. In exploring such possibilities, an integration between crop, livestock and fish, for the full utilization of resources, we have been gifted by the Nature, could probably be the answer to our problem. In the present paper a detailed account of existing integrated farming system in India and abroad with suggestions to improve upon, taking into consideration the drawbacks and available resources, is presented.

INTRODUCTION

ROUGHLY 2/3 of the total land area available in world is covered with water of various descriptions, of which approximately 97% belongs to the ocean and the rest is freshwater. Man through ages has been practising hunting, agricultural farming, fishing and domestication of animals for obtaining food and other necessities of life. The culture/taming of aquatic creatures, very frequently termed as aquiculture or aquaculture too is not new to us. What we lack, is the knowledge of judicious integration between all the available resources from which we could obtain food, other products and byproducts for better living. Integration literally means to join or link up different parts together. Similarly integration between different methods/sectors/operations/ resources from which we could get optimum protein, is the present-day need. Here we would like to discuss, that how best can we put our land and water bodies to maximum use in order to get optimum return out of these, so that, no part of land or water area is left unused. India with its vast natural resources, where main occupation is agriculture, which is estimated to increase 3.89% during the period from 1978-79 to 1983-84, by Government of India, can profitably utilize resources indigenously and cheaply available in the country by integrating the operations involved in agriculture and aquaculture.

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AIMS AND GOALS

The main aims are to raise crop production ; rise fodder production ; raise animal protein ; supply nutrients to soil ; utilize/exploit wastes which are often termed as resources out of place ; mainly organic wastes ; conserve energy and generate power ; synthesise farm products ; reduce health hazards ; reduce expenses involved in labour indisposal of wastes and utilise land and water body available in the country.

Practical Utility

When we think in terms of integration of crop with livestock and fish, we have to study their origin behavioural pattern ; availability of resources, methods and drawbacks for their proper maintenance and optimum utilization. In India large number of domestic animals like cattle, pigs and birds which obtain their nutrient from crops, more often complete for their food with human beings. By learning better system of integration we can adapt our animals to different cheap substitutes/supplements like, urea-molosses feeding to cattle (Pathak *et al.*, 1973 ; Pathak and Ranjhan, 1976 a, b ; Pathak *et al.*, 1976 a, b ; Krishna Mohan *et al.*, 1976 ; Ranjhan *et al.*, 1976), digested Slurry from biogas plant to sheep (Saxena *et al.*, 1979), to pig (Pathak *et al.*, 1978) water hyacinth to pigs (Pathak *et al.*, 1978 a, b, c), ensiled poultry excreta to dairy cattle (Jayal *et al.*, 1979 ; Jain *et al.*, 1979) and fish meal to pigs (Jayal *et al.*, 1978). Use of cowdung, poultry excreta and pigs excreta and human waste is also not unknown in pisciculture. By utilizing the waste and animal organic wastes as well as adapting our animals to cheap and nutritive ration, which is not fit for human consumption, we can not only save food grains but also produce animals protein, crop protein and solve the problem of hunger and health hazards which arise out of ill disposal of such wastes.

In India the major portion of animal excreta is either burnt or goes waste (Ranjhan, 1977) and very little is used as a source of nutrients supply to agricultural land and water bodies under fish culture. Like crop rotation in agriculture where the land is kept occupied all the year round by a standing crop or the other, we can manage our livestock, fish culture and agriculture in such a way that no resource product or by-product is left unutilized.

Discussion

In countries like Singapore and China fish culture, mainly carp culture is done on commercial basis by Chinese or as a subsistance crop by Malays which is the integral part of farm operation, which includes fruits, vegetables and livestock as well as cash crops like tobacco and rubber. Excess of fertilizer from compost and soil minerals from all terrestrial crops eventually find its way to fish ponds which are usually constructed at lower levels. Birds and human inhabitants also contribute their share to organic nutrient supply. In China manure from pig sty is periodically washed into fish pond where usually no other fertilizer is used. In times the pond becomes dilute solution of fertilizer which is used to irrigate crops. Periodically the sludge so formed is dug out and applied to vegetable beds. Pigs are also used as a store house of fertilizer for Chinese carps, in Hong Kong, Thailand and Kwangtung province of China. In Hong Kong 100 pigs of 30 kg each or 2500 ducks of 1 kg each are kept in pens overhanging the fish pond and excreta from these animals, roughly 3,65,000 kg and 2,500 kg per year respectively calculated @ 10 kg/day and 25 kg/year respectively is said to be sufficient for 1 ha. pond. In south China and Indonesia even leterines are built over fish ponds (Bardach *et al.*, 1972).

Some references are available on Crop cum fish culture in Thailand, Malayasia and Singapore where waters spinach (*Ipomoea reptans*) is grown in deeper ponds where primary crop is either fish or freshwater shrimps. Water-spinach is used as cheaper vegetable and also as livestock feed. It is reported to produce 100 kg of green matter per ha./day. The average plant contains 92% of water, 2.1% crude protein and

2.9% carbohydrate (Bardach *et al.*, 1972). In India too water spinach, water cress, water chestnut and paddy are extensively grown where fish is grown as a secondary crop.

Prospects of fish culture are not particularly bright for an increase in world production of fish from land bound or land related environment such as rivers, lakes, ponds, coastal and estuarine areas of the world. This is partly true because such efforts have been and will remain largely a way of converting less expensive fish into lesser amount of more expensive fish. Indeed recent development in the world seem to limit the prospects. Pesticides and herbicides used in connection with the production of rice and harvesting more than one crop a year from the same paddy have already begun to sharply limit the mixed croping of fish and rice practicised in southeast Asia for many years (Sprague, 1973).

Scientists at CIFRI in their experimental trials have been able to produce 5,500 kg paddy/ha alongwith 700 kg of fish (Hindustan Times dated 26th May 1979). In this technique paddy field is converted into a perimeter canal where fingerlings of major carps are stocked. Paddy is grown in Kharif from June to December. When paddy is harvested, fish move to perimeter canal so constructed, where they grow till Ravi crop is harvested. Even domestic sewage is being popularly used in agriculture, pisciculture and horticulture, in many parts of the country and abroad (Jhingran, 1974).

Keeping in view with present-day need attempts have been made to formulate different programmes/projects in this direction. Some of the programmes which are already under way are appended below.

Fish culture in domestic sewage

Scientist at CIFRI have been able to produce 7,000 kg/ha of Rohu, Catla, Mrigal, common crop and silver carp at Rahara (West Bengal). A similar project on air breathing fish culture, in ponds fed with domestic seawage is underway.

Composite fish culture without artificial feed

Composite fish culture, a term generally applied to culture of such spp. of fish which feed on the food available in different ecological niches of fresh water with artificial feed. A similar project on culture of Rohu, Catla and Mrigal in association with axotic carps viz. common carp, silver carp and grass carp without artificial feeding in livestock sewage fed ponds is in progress.

Culture of forage fish

For the purpose of providing better nutritious feed to livestock and fish for more protein yield like meat, egg food fish and milk etc., sewage culture of Tilapia and other easily proliferating spp. of fish is already prevelent in India. Similar experiment is being conduced at I.V.R.I., Izatnagar on Tilapia culture in ponds solely fertilised with poultry excreta.

Culture of Tilapia in pig shed washings

Utilising the nutrients present in pig excreta, a project on culture of tilapia for production of fish meal is underway.

Tilapia culture in cattle shed washings

Tilapia culture utilising nutrients present in cattle urine and shed washing is also under study.

Algae culture in cattle urine and shed washings

Keeping in view the nutrient value of algae, experiments on algae culture mainly spirulina and chlorella using the substrate-cattle urine and shed washings are already in progress.

Based on the data available and specific requirement of the particular land of the Institute a suitable combination of animals whose excreta is sufficient to supply nutrients in terms of N : P : K to 1 ha pond has been worked out (Table 1 and 2). Based on the local value of inputs and outputs a model of economics (Rough estimate) of the integrated farming system has also been prepared (Table 3).

TABLE 1. *Percentage nutritive value in terms of N : P : K of livestock wastes*

Farm Animals	N	P_{2O5}	K_{2O}
Cow (Urine)* ..	0.60	0.10	0.40
Goat (Urine) ..	0.40	0.002	0.48
Sheep (Urine) ..	0.40	0.002	0.48
Pig (Excreta)* ..	0.60	0.50	0.50
Birds (Excreta)* ..	1.47	1.15	0.45

* Garg, 1971

TABLE 2. *Integration, of farm animals to be kept in order to meet the nutrient requirement of 1 ha pond of the Instt.*

Farm Animals	N	P_{2O5}	K_{2O}
7 Cows ..	308.000	5.300	225.700
5 Sheeps/Goats ..	34.000	0.200	36.600
5 Pigs ..	22.500	17.000	19.000
50 Birds ..	18.400	14.400	6.000
67 Total ..	382.900	81.900	287.300
Calculated ratio NPK	4.5	1	3.5

(The above data has been calculated assuming the rates of urination and excretion of the animals in cronological order as 7,300 Litre, 1,825 L., 1,825 L., 750 kg and 25 kg/year respectively.)

TABLE 3. *A model of economics (Rough estimate) of the integrated system*

Size of family : 5 Adults Size of holding : 2 Hactares

Class of animals	Nos.	Value Rs.	Feeding cost/ year Bio-system slurry Agricultural byproducts Rs.	Wastes output in kg.	Valuation in rupees	Anticipated yield of fish kg.	
Cow	7	7000.00	5110.00	51100.000	2044.00	8000 to 10000 to	64000.00 80000.00
Sheep/Goats	5	500.00	1095.00	9125.000	365.00	—	—
Pigs	5	1000.00	1825.00	18250.00	365.00		
Poultry birds	50	500.00	9125.00	1250.000	12.50		
Biogas plant (100 cft.)	1	3000.00	—				
Fish Fingerlings		500.00					
Total		12500.00	17155.00		2786.50		80000.00

Note : (1) Feeding cost per day cows @ Rs. 14, Goats/sheeps @ Rs. 3, Pigs @ Rs. 5 and birds @ Rs. 25.

(2) Cost of wastes/quintal cattle excreta @ Rs. 4.00, sheep & goats @ Rs. 4.00, pigs @ Rs. 2.00 and birds @ Re. 1.00.

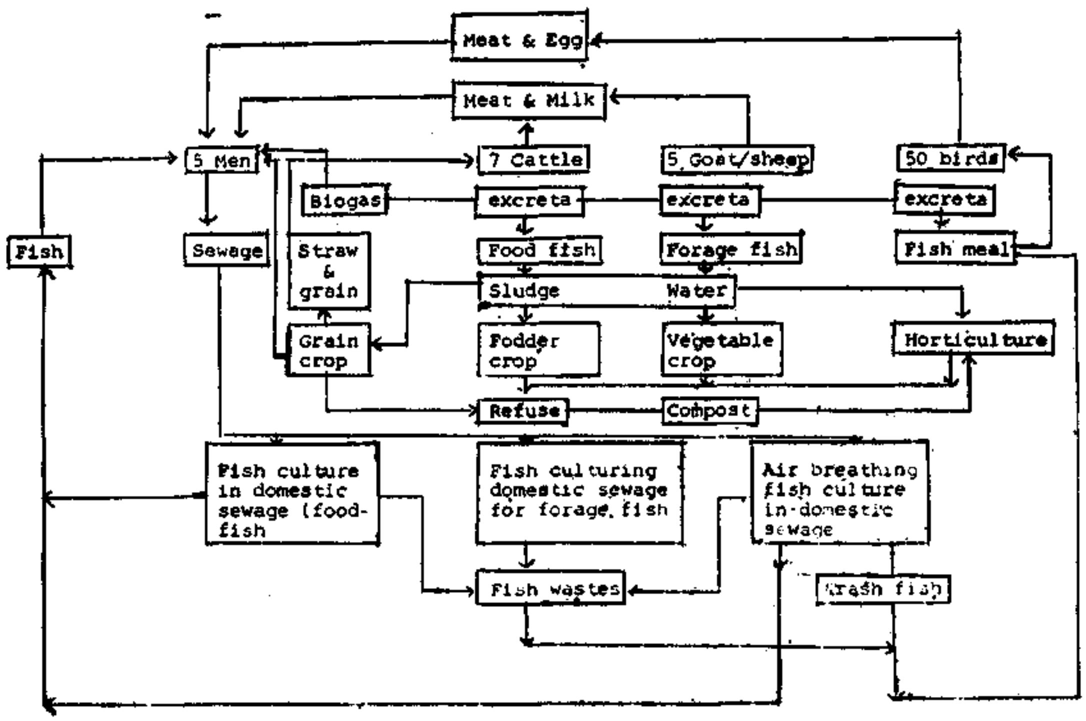
A. Animal produce—milk, wool, Piglets and eggs are estimated to fetch approximately Rs. 20,000.00/year.

B. Ration formula consisting of concentrate mixture with the percentage composition of D.O. Rice Bran, D. O. G. N. Cake, Dal chuni, urea, molasses, mineral mixture, salt and vit. A (Rovimix) is estimated to provide 17.5% D.C.P. and 65% T.D.N. costing Re. 0.60 per kg.

C. By products *viz*. Wheat bhoosa, paddy straw, Slurry, seasonal weeds and grass and vegetable refuge available from the system would form the roughage/fill-moiety of the animals.

D. Biogas would provide energy for fuel and lightening.

DIAGRAMATIC REPRESENTATION OF PROPOSED CROP-LIVESTOCK-FISH INTEGRATED FARMING



Legal aspects involved in utilisation of organic wastes

The problem of managing fisheries in inland water bodies and coastal zones appear to be less complex than managing high seas commercial fisheries, because they are wholly within the jurisdiction of a single state, but the problems are in fact no less difficult. Alternative and competing uses involving both living resources and other uses of inland waters and coastal zones as well as ocean must be balanced without detriment to environment. Often one has to face concerted economic and political pressure in managing such system. on One hand the waters must be managed, for the needs of better commercial fisheries and recreation. On the other hand, the coastal zone and inland waters should be managed in such a way that increasing disposal of domestic and industrial wastes which are in some areas have proved harmful to living resources, and increasing industrial resources for the exploration of petroleum and minerals does not pollute/change the environment of living resources. The problem has to be reconciled by integrating the various uses of the marginal seas, inland waters and land area. Sufficient knowledge has to be acquired through extensive research, seminars, symposia and open house discussions to provide a basis for incompatible uses of water bodies under reference.

In the last a multi disciplinary approach like integration between land and water resources has become the utmost necessity. It is hoped that by follow up action towards this system we would be able to ensure a sustained harvest of edible protein from land as well as water bodies for as long as needed by us.

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ECOLOGY OF CULTURE PONDS IN COASTAL REGION OF SUNDERBANS

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ABSTRACT

In Sunderbans of lower deltaic West Bengal, the salts in soils of intertidal zone is quickly released when it comes in contact with rain water accumulation. Further the piezometric surface in the area being at a lower level, the released salts leach down the pond bottom and normally get fixed in the bottom clay lattice. Consequently the salinity of water rapidly decreases. This changes the composition of micro-aquatic species of the ecosystem providing scope for polyculture of euryhaline commercially important cultivated estuarine species of fish and prawns along with Indian and exotic freshwater carps. For this purpose, 1.8 to 2.0 m deep rainfed 0.25 ha ponds have been fertilised with N and P in the ratio of 3 : 2 @ 600 kg/ha/year after giving a basal dose of cattle during @ 10,000 kg/ha. The plankton, comprising mainly of *Daphnia* sp., *Diaptomus* sp. and *Cyclops* sp. among zooplankton and *Coscinodiscus* sp., *Synedra* sp., *Ulna* sp. and *Nitzschia* sp. among phytoplankton increases from 100 to 780 units/1 after manuring. The ponds have been stocked with 3044 nos. of fish and prawns with 39.8% Indian and exotic carps, 47.4% brackish water fishes and 12.8% tiger prawn. A net production of 2529 kg/ha/yr has been obtained.

It has been further observed that when the salinity goes down below 2.0‰, the water in these ponds turns turbid and inhibits sun ray penetration and ultimately affects planktonic growth. This resulted in the decrease of fish production. However, this phenomenon can be corrected with the introduction of heavy amount of organic compost @ 15,000 kg/ha or mohua oil cake.

INTRODUCTION

IN THE DELTAIC region of lower Sunderbans of West Bengal, the salt of pond bottom soils is quickly released when it comes in contact with rain water precipitation. Further, the ground water table, or the piezometric surface in the deltaic region, is at a low level and therefore the salt released from the soil leach down the pond bottom and normally get fixed in the bottom clay lattice. It has, therefore, remote chance of revival from the mud bottom (Banerjee *et al.*, 1976). This results in rapid decrease of water salinity in the ponds excavated in the intertidal zone of Sunderbans. This changes the composition of micro-aquatic species of the ecosystem providing scope for polyculture of euryhaline commercially important cultivated estuarine species of fish and prawns along with Indian and exotic freshwater carps. According to Conagaratnam (1959) better yield is obtained by the exchange of freshwater with saline water in fish ponds. The ecology of 0.25 ha ponds in lower Sunderbans have been studied and the results embodied in the present communication.

MATERIAL AND METHODS

Two 0.25 ha excavated ponds of about 2.0 m depth on Henry's Island in lower Sunderbans have been taken up for the study. The ponds contain only rain water. The physico-chemical conditions of water *viz.* pH, phosphate and nitrogen have been determined following the standard methods of water analysis (APHA, 1965). In soil, pH, organic carbon, available phosphate and available nitrogen have been worked out following Piper (1957). The salinity of water and soil (water extract) have been determined by standard titration method. The plankton samples have been collectea by filtering 100 litres of water through bolting silk plankton net of 25 count. The methodology followed for analysis of plankton has been described by Jhingran *et al.* (1969). When the water salinities of the experimental ponds have come down to 3 ppt after 2 year , these have been stocked with 39.8% Indian and exotic carps, 47.4% brackishwater fishes and 12.8% tiger prawn.

Results

Physico-chemical conditions (water phase)

The physico-chemical properties of the pond water indicating the range and the average are shown in Table 1.

pH

The water pH ranges from 7.2 to 7.9 during first year (1971) of observation and a slight increase in pH 7.6-8.6 has been noted later.

Salinity

The water salinity, which ranges from 1.3 to 3.2 ppt during the first year, has come down to 0.35 ppt in the fourth year (1974).

Phosphate and Nitrate Nitrogen

The gradual decrease of phosphate and Nitrate Nitrogen of water have been enriched by organic and inorganic manuring and the range finally has come up to 1.8 and 4.2 ppm respectively.

Primary productivity

The values of primary productivity are quite satisfactory and it ranges from 240-603 $mgC/m^3/hr$ which, however, has declined to 200-254 $mgC/m^3/hr$ in the fourth year (1974).

TABLE 1. *Physico-chemical condition of the water of the ponds*

Year	pH		Salinity (ppt)		Nitrogen NO_3 (ppm)		Phosphate PO_4 (ppm)		Prim. Productivity $mgC/m^3/hr$	
	range	average	range	average	range	average	range	average	range	average
I ..	7.2-7.9	7.5	1.3-3.2	1.8	.08- .80	.48	08- .10	.09	240-603	356
II ..	7.4-8.0	7.8	1.26-2.7	1.6	.02-1.3	.80	.02- .19	.14	270-424	320
III ..	7.4-8.4	8.0	.77-2.7	1.6	.30-0.70	.50	.12-.60	.42	270-356	300
IV ..	7.6-8.6	8.2	.35-.85	.66	.18-1.8	1.2	.21-4.2	2.6	200-254	230

Temperature and Rainfall

The water temperature has been found to vary from 17.1 to 32.5°C (the maximum being in the month of May and the minimum in December/January). Rainfall in the area ranges from 1680 to 1800 mm per year and average rainfall is 1720 mm/year.

Characteristics of soil

The soil samples, analysed once in 3 months, have shown nominal concentrations of nitrogen *i.e.*, 4.8 to 9.4 mg/100 g at the onset. But after manuring, it is raised to 12.7 to 22.0 mg/100 g. Phosphate in soil has been found to be comparatively high and the average ranges from 15.4 to 20.4 mg/100 g in 4 years (Taole 2).

Phytoplankton

The production of phytoplankton is good, fluctuating from 700 to 6,400 L, the dominant forms being of *Coscinodisous* sp., *Synedra* sp., *Ulva* sp., and *Nitzschia* sp. There is a decreasing trend in plankton population with the decrease of salinity of water.

Stocking and Production of Fish

The ponds have been stocked with estuarine fish and prawn species along with Indian and exotic carps at the rate of 10,220/ha of which 39.8% is Indian and exotic carps, 47.4% brackishwater fishes, and 12.8% tiger prawn. Net production of 1,686 ka/ha/8 months has been obtained in the first year. In subsequent 3 years the productions have been 1672 kg and 1630 kg and 1472 kg/ha respectively.

TABLE 2. *Soil characteristics of the ponds*

	pH		Salinity (ppt)		Av. nitrogen N_2 mg/100 g		Av. Phosphorus P_2O_5 mg/100 g		Organic Carbon %	
Year	range	average	range	average	range	average	range	average	range	average
I ..	6.6-6.8	6.7	.4-1.6	.92	4.8-9.4	6.2	14.2-18.4	15.4	1.62-1.86	1.71
II ..	6.6-7.0	6.7	.5-1.6	.84	6.1-6.7	6.3	10.3-21.2	18.4	0.84-1.53	1.1
III ..	6.6-7.2	6.8	.4-1.2	.68	6.7-13.7	11.2	11.3-23.0	18.6	0.87-2.1	1.34
IV ..	6.7-7.2	6.8	.45-1.2	.72	13.7-22.0	16.4	15.1-33.0	20.4	1.3-2.1	1.54

Zooplankton

Among zooplankton, the dominant species are *Daphnia* sp., and *Cyclops* sp. and the concentrations are 100 to 1300/L. Similar decreasing trend has also been noted in plankton density with decreasing salinity.

Fertilization and Manuring

As the source of nutrient is limited (Banerjee *et al.*, 1975), the ponds have been fertilized with N and P in the ratio of 3 : 2 at the rate of 600 kg/ha/year after giving a basal dose of cattle dung at the rate of 10,000 kg/ha. In subsequent years (1972-74) they have been fertilized with raw cattle dung at the rate of 3,000 kg/ha and poultry manure at the rate of 1,500 ka/ha.

DISCUSSION

Reviewing the water quality and soil conditions during the course of the observation, it is revealed that water salinity has a fast decreasing trend as well as that of the soil salinity. As the piezometric surface in the area has got no capilarity, the possibility of the leached out salt coming back to the pond system is negligible. Thus the decrease in water salinity continues. The nutrients like nitrogen and phosphate have also been found to follow the same trend. Manuring with inorganic fertilizer N and P in the ratio 3 : 2 along with a basal dose of cattle dung has been resorted to for maintaining favourable nutrient status in the ponds; ultimately resulting in the increase of primary productivity from 240 to 603 $mgC/m^3/hr$ and enhancing fish production to 2,529 kg/ha/yr.

In subsequent years (1972-74), the application of poultry manure at the rate of 1,500 kg/ha, along with cattle dung have sufficiently increased the nitrogen and phosphate level both in water and soil phase. But this has vrey little impact on the productivity and planketon population; primary productivity has gradually gone down to an average of 230 $mgC/m^3/hr$ in the 4th year (1974). It is noted that the water salinity has been going down very fast (0.35 ppt) and this may be the cause of low productivity. The prolonged low water salinity seems to have created the problem of sustained turbidity in the ponds because of colloidal suspension. This sustained turbidity adversely affects the development and growth of plankton population and benthos, essential for growth and survival as it is inhibiting sunray penetration. The problem of turbidity, however, can be overcome by electrolytic dessociation of the colloids by adding (pumping) saline water into the system. Another effective measure has been evolved by the treatment of the pond with heavy amount of organic compost at the rate of 15,000 kg/ha and simultaneously raising the salinity of the water to 2.0 ppt.

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AN IMPROVED DESIGN OF A SLUICE FOR A MARICULTURE FARM

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ABSTRACT

Traditional designs of sluices connecting the main feeder channel to a common tank or a series of tanks in a Mariculture fish farm have been of either closed box type or open with no roof, using wood and sliding shutters in grooves. Currently, irrigation sluices with a worm and screw shutter have been set up in India. There has been little experimentation on improvement of the design. This paper describes a model tested sluice of improved design which is capable of controlling the flow of water at any desired level automatically without attention. The design also enables sorting out the migrating fish and fry into the feeder channel. Both wooden and monolithic construction can be resorted to.

INTRODUCTION

MARICULTURE, particularly shrimp farming has recently received considerable attention from planners, industrialists and scientists in India. Extensive areas have been reported to be available in the various maritime states and union territories of India. Our present technical achievment is still inadequate for different environmental conditions and economic shrimp culture is limited to areas with favourable tidal conditions along with other relevant ecological factors. Economics of shrimp farming in farms in which water supply is maintained by pumping requires further experimental work and critical economic review.

In commercial farms, the design has to be strictly functional without sacrificing efficiency and the capital costs have to be low. An important part of the design is the main sluice connected to the feeder channel. An attempt has been made, in this paper, to design a strictly functional sluice which will be economic in labour costs and the capital cost will be reasonable.

DESIGN CONSIDERATIONS

The main sluice is required to perform the following functions. (1) It should have suitable opening to fill up at least one fourth of a farm in one tide. (2) There should be little leakage through the sides, bottom and through shutters. (3) The anchorage of the sluice should be firm. (4) The shutters should be such that the flow of the water can be adjusted at any level both for ingress and outflow. (5) The control of the flow should be automatic after the desired level has been fixed. (6) The arrangement of the structure at the end of the inlet should be able to filter and keep the migrants in live condition till sorting can be done. (7) The sluice can be used for scouring with a suitable arrangement for the water flow. (8) The material used should be able to withstand saline water erosion for a long period.

APPROACH TO THE PROBLEMS

A study of the existing sluices was made in the field. In most cases the sluice was a wooden frame box of sturdy construction to withstand side pressure. Shutters were sliding planks manually operated. The level could be controlled only from the bottom. All adjustments were done by attending labour and vigilance had to be exercised frequently. In one farm an irrigation sluice with worm and screw shutter had been used. This could also control flow of water only from the bottom. The adjustment of the height of the flow had to be attended to frequently. There was seepage from the bottom requiring bags filled with sand to stop seepage. Wooden sluices did not have much seepage problem either through the sides or from the bottom. An open roof frame type could not be studied in the field. It is reported that this type avoids water turbulence leading to scouring when the water level goes beyond the water level and the pressure of incoming tide creates a heavy current. Some sluices constructed with boulder in cement were found to be broken and even when the walls were intact there was considerable seepage. A monolithic sluice designed by the author for the Kausalyaganga fish farm with worm and screw shutter was found to have excellent arrangements to trap the migrants and keep them in live condition for periodic sorting. With the field studies and also study of literature a model sluice was designed and tested in model conditions. After periodic modifications the sluice finally was found to be functional and considered suitable for field application.

Design

Out of the tests three types of ground plan emerged. All of them utilise the current for automatic closing of shutters which can be adjusted to the desired level. Flow of water outwards through the bottom most opening results in scouring of silt, specially when the main channel has another sluice at the other end. The shutters are of wooden planks fixed to hinges at the 2 ends. In case of inflow the water freely enters but as soon as the flow is reversed the shutters close. Each shutter can be adjusted separately either to remain closed or work one way.

Type I. This is an open roof type sluice with non return valves. There is no arrangement for trapping the migrants.

Type II. In addition to the above there is a built in trap to catch the migrants into the channel and keep them in live condition.

Type III. This is Type II added with a trap at the outflow end to catch the fish when water is being drained out.

Types II and *III* are meant for organised farms. These can be constructed in Mono block concrete without any foundation problem in deeply silted channels. The abutments are easy to make and long lasting.

Design calculations for specific planning include water requirement, tidal height, weight of the sluice and required concrete structure, cusecs flow to miminise water turbulence inside the traps and building material. These need detailed study.

Conclusion

All the three types have been made into models made of wood and tested in water channels and found to be workable. It is necessary to construct regular sluices based on these principles and further improvement will naturally result.

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ON DESIGNING VENT OF A SLUICE WORKING UNDER VARYING HYDRAULIC CONDITIONS FOR BRACKISHWATER FISH FARM

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ABSTRACT

Unlike common types of irrigation sluices constructed mainly for the purpose of draining out accumulated water in the countryside to the tidal or taking in water from the reservoir to the irrigation canal under specific water head, the sluices in the brackishwater fish farm will work under constantly varying water head and current velocity in different tidal phases.

The sluice should be designed such that it can feed the farm efficiently and also help in draining out the farm as per requirement ; and to attain this, the proper design of the vent of the sluice is most essential.

The present article is based on the tidal data collected from the river near Kakdwip Research Centre. It has been noted that the fluctuation of the tidal rise as well as the current velocity in the estuary under study follow a regular order. Attempt has been made to study and interpret it graphically and subsequently a simplified mathematical formula has been evolved which may be useful in designing the required vent area of the sluice of a brackishwater fish farm. The result obtained from the mathematical formula has been compared with the result evolved from the graphical study for further verification and the final conclusion has been ultimately drawn.

INTRODUCTION

UNLIKE the common type of irrigation sluices constructed mainly for the purpose of draining out accumulated rain water in the countryside to the tidal river or taking in water from the reservoir to the irrigation canal under specific water head the sluices in the brackishwater fish farm is destined to work under constantly varying water head and current velocity under different phases of a single tide.

In the case of ordinary drainage or irrigation sluices the vent area is designed mainly on the basis of the required discharge and available upstream water head. The same vent area is in function throughout the period of discharge since the vent will act as a submerged orifice. Discharge velocity will not also change since the hydraulic head is constant. But in the case of open type of sluices in brackishwater farm the effective area of vent itself changes with the change in the height of the tidal water and effective height of the vent virtually equalises with the height of the tidal water above the floor of the sluice. Moreover in this type of open sluices connected directly to the tidal creek there will be a non-modular flow and the velocity will be directly related with the velocity of the tide in the creek.

The vent area of a brackishwater farm should be designed such that it can allow sufficient volume of tide water to enter the farm so that the farm ponds can be filled up with water upto the required depth in consecutive five or six spring tides.

Although Juichi Kato (1975) has worked on designing the width of a sluice working under tidal phases he treated the orifice of the sluice to be submerged always under water. No attempt has been made so far to study the free flow in the open channel of a sluice. An attempt has been made in the present paper to peep into the actual tidal phenomena in the estuaries and to evolve a comprehensive mathematical formula which can be easily applied to design the width of a brackishwater farm sluice.

Material and Methods

A tidal gauge has been fixed near the mouth of the existing sluice on the tidal creek which is connected with the Bartala river, a part of the Hooghly-Matlah Estuary system, near the Bay of Bengal. The tidal height has been recorded round the year in the spring tides on the tidal gauge in the regular intervals of ten minutes and current velocity has been also noted simultaneously by using the partly submerged float. In the present paper tidal readings of a particular day has been shown (Table 1) only and two mean curves have been drawn showing these two variables in respect of time (Fig. 1). A third curve is drawn by showing the value of multiplication of those two variables in respect of time and the curve represents the discharge per unit time for different phases of the tide. Since the tidal readings of all the spring tides of the year bear the same characteristics the readings dealt with in present discussion can be taken as a representative one.

TABLE 1. *Observations on velocity of current, height of tidal rise and discharge in respect of time*

Time (Hr. mts)	Velocity (cm/sec)	Height (cm)	Discharge (cc/sec)
7-15	8.48	0	0
7-25	9.42	25	236
7-35	9.42	58	549
7-45	7.70	95	735
7-55	10.6	140	1482
8-05	11.45	161	1860
8-15	12.11	192	2348
8-25	14.13	213	3048
8-35	6.05	235	1420
8-45	14.13	256	3650
8-55	15.70	287	4550
9-05	16.96	309	5210
9-15	21.20	349	7810
9-25	24.94	385	9600
9-35	28.26	410	11600
9-45	28.26	425	12000
9-55	38.54	435	16800
10-05	42.4	446	18850
10-15	10.6	451	4900
10-25	7.70	445	3421

Hydraulic Observation

From Fig. 1a it is evident that the curve of the tidal rise is close to a sine curve with a constant periodicity. Fig. 1 is close to a linear curve. Tidal observation has been taken only for 3 hrs till the tide rises to the peak level. Since low water level observation data is not available and total duration of tide was observed to be 6 hrs the low water level can be known by applying the following correction as per Kato (1975).

$$H = \frac{2h}{1\text{-}\cos\frac{\pi t}{t'}}$$

Where H = tide range

h = difference in elevation between high water level and the limit of observation.

H = time to reach high water level from limit of observation.

t′ = time required to reach high water level from low water level.

Substituting the value of h and t′ in the equation,

$$H = \frac{2 \times 446}{1 - \cos\frac{\pi \times 3}{6}}$$

or $H = 2 \times 446.$

So $h = \frac{H}{2}$

Hence it is evident that in the present case the zero mark of the tidal gauge coincides approximately with the mean sea level.

The curve 1A can be expressed by the following equation :

$$h = C \sin \frac{\pi}{2} \times \frac{t}{3} \text{ (t in hrs)} \ldots (a)$$

where C is a constant.

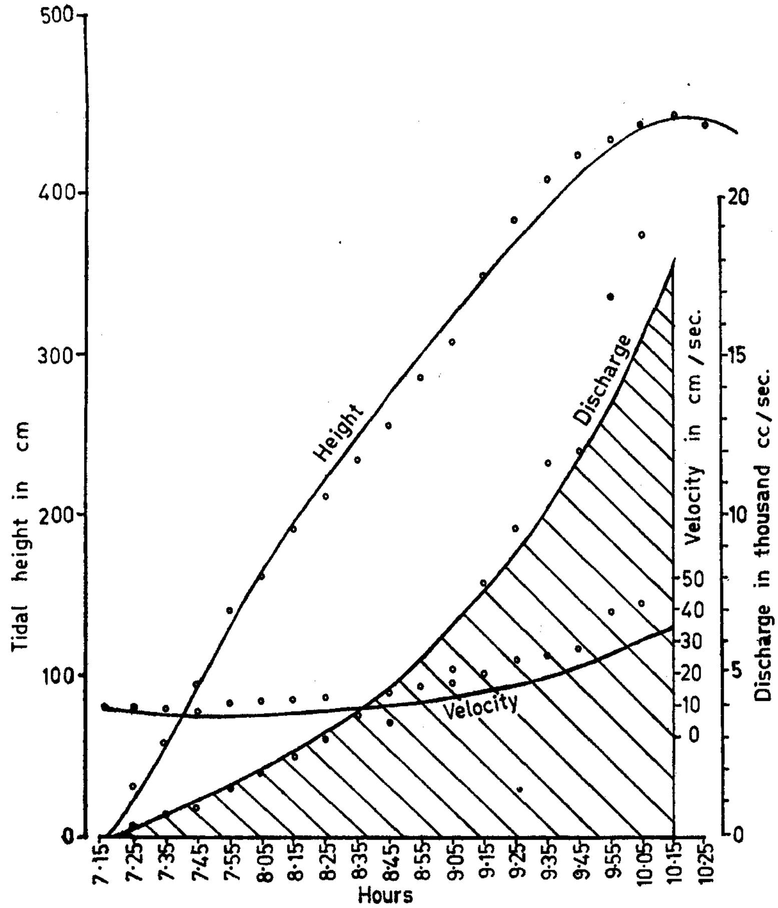

Fig. 1. **Height, velocity and discharge curve.**

Now when t = 3, h = 446 cm, substituting the values in equation (*a*),

$$446 = C \sin \frac{\pi}{2} \times \frac{3}{3} \text{ or } 446 = C$$

Mathematical Formulation

The relationship between the discharge, current velocity and the rise of tide water in the vent of unit width can be expressed as follows :

$d\,Q = hv\ dt \ldots\ldots (b)$ when Q = volume of water entering through the sluice (cc), h = height of tide water above the floor of sluice (cm), v = current velocity (cm/sec).

Now v = f(t) and though it is not strictly a linear function, for simplifying the calculation it can be treated as a linear one.

Let v = kt, where K is a constant. Substituting the value of v and h in equation (*b*).

$$dQ = C \sin \left(\frac{\pi t}{6}\right) \times kt\ dt \ldots\ldots\ldots (c)$$

or $$dQ = Ckt \sin \frac{\pi t}{6}\ dt$$

Integrating both sides

$$Q = Ck \quad \sin \frac{\pi t}{6} \times dt$$

$$\text{or } Q = Ck \left[\frac{\sin \frac{\pi}{6} t}{\left(\frac{\pi}{6}\right)^2} - \frac{t \cos \frac{\pi t}{6}}{\frac{\pi}{6}} \right]_0^3$$

$$\text{or } Q = Ck \left(\frac{6}{\pi} \right)^2 \ldots\ldots (d)$$

$$\text{Now } K = \frac{\text{Final velocity} - \text{Initial velocity}}{\text{Time period}}$$

$$\text{or } K = \frac{42.4 \times 3600 - 8.48 \times 3600}{2.83}$$

$$K = \frac{33.92 \times 3600}{2.83} = 43149$$

From equation (*d*) the numerical value of Q can be deduced for the present case, Substituting the values of C and K in the equation (*d*),

$$Q = 446 \times 43149 \times \left(\frac{36}{\pi} \right)^2$$

$$\text{or } Q = 70000000 \text{ cc}$$

Now from the curve 1 C total volume of discharged water will be given by the total shaded area and by actual measurement also it comes 63300000 cc only which is very close to the value 70000000 cc obtained from the given formula. Thus the validity of the formula evolved earlier has been established and it is proved that the tide curve is a sine curve in nature.

Discussion

Although the formula has been deduced on the basis of the tidal readings taken at a particular estuary for a particular period, since the basic tidal phenomena will generally follow the same rule everywhere with the variation in degree only, the deduced formula can be applied in general with the appropriate values of C and K. The formula (*d*) is applicable only in the case where the floor level of the sluice flushes with the mean sea level. In other cases when the sluices will have to be designed below mean sea level so that tide water can be taken into the farm for longer duration a more generalised formula should be evolved. If the level of the floor is C' below the m.s.l and t' be the time in hrs required for the tide to reach m.s.l. from the floor level of the sluice, by changing the axes of equation (*c*),

$$h - C' = C \sin \frac{\pi}{6} (t - t')$$

$$\text{or } h = C' + C \sin \frac{\pi}{6} (t - t')$$

Substituting this value of h in equation (*b*),

$$dQ = \left[C' + C \sin \frac{\pi}{6} (t - t') \right] kt \, dt$$

Integrating,

$$Q = K \left[\frac{C' t^2}{2} + C \left\{ \frac{\sin \frac{\pi}{6} (t - t')}{\left(\frac{\pi}{6}\right)^2} - \frac{t \cos \frac{\pi}{6} (t - t')}{\frac{\pi}{6}} \right\} \right]_0^{t + t'} \ldots\ldots (f)$$

The equation (*f*) will serve the purpose of calculating the total discharge through the sluice gate of unit width upto the peak tide hour and on the basis of total requirement of water volume in the farm the required width of the sluice can be worked out easily.

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FISH AND SHELLFISH DISEASES AND THEIR CONTROL

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ABSTRACT

Disease control in aquaculture depends on three significant factors : (1) correct *diagnosis* and understanding of the life cycle of the causative agent ; (2) *preventive measures*, such as maintenance of water quality, provision of an adequate diet, prophylactic immunization, and reduction of environmental stress ; and (3) *treatment*, usually in the form of chemotherapy. This paper is concerned largely with infectious diseases, but it is apparent that poor water quality and inadequate nutrition are often basic determinants of disease outbreaks in culture systems. There are of course frank pathogens such as *Aerococcus viridans* in lobsters, Microsporida in fish, which must be excluded from culture systems, but the greatest damage seems to result from facultative microorganisms - often part of the natural flora—which affect stressed culture populations. Stresses may take the form of overcrowding, inadequate diets, oxygen deficiency, buildup of metabolic byproducts, toxic chemicals from external sources, temperature variations, and a number of other less obvious features of what is at best an abnormal environment for marine animals. Control measures, therefore, should emphasize reduction of stresses, and chemotherapy should be considered as a 'last resort' method. However, this does not mean that chemotherapeutic methods should be ignored, since they must be available if other control measures fail. Excellent progress has been made in the elaboration of chemical treatments for fish and shellfish diseases.

One serious handicap in chemical disease control is the slow clearance and approval from government regulatory agencies for legal use of certain chemicals. Adequate testing must be done before chemicals can be cleared for use on fish and shellfish destined for human consumption. The testing is slow and expensive. At present, for example, very few such chemicals have been cleared for use by the Food and Drug Administration of the United States. Thus, even if a substance has chemotherapeutic properties useful in marine aquaculture, it may not be used legally. This is true at present for the entire class of nitrofurans developed initially in Japan.

A more positive approach to disease control is that of prophylactic immunization. Vaccines have been developed to reduce the effects of vibriosis in salt-water reared salmon, and other microbial diseases of fishes are susceptible to similar methods of control. Some of the larger invertebrates—notably the lobster—have been found to be immunologically responsive, and some protection has been demonstrated against at least one disease (Gaffkaemia) using live vaccine preceded by antibiotic injection. With newer methods of vaccine application, treatment of entire cultured populations becomes feasible.

In summary, much has been learned within the past few decades about diseases affecting principal aquaculture species, and control measures to reduce their effects. Some problems persist and much remains to be done, but it seems that the technology of disease control—one of the bases for successful large-scale commercial aquaculture—is progressing satisfactorily.

Introduction

GREAT progress has been made in the diagnosis, treatment, and control of human diseases during the past century. Identification of pathogens, prophylactic vaccination, ecological control measures, antibiotic and other treatments—all have progressed remarkably.

The same principles that were elaborated so slowly during the emergence of knowledge about human disease outbreaks apply, of course, to aquaculture populations of fish and shellfish—in fact there are many obvious parallels that may be drawn between shrimp or fish populations in ponds and human populations crowded into cities. Those responsible for aquaculture operations cannot afford to ignore these parallels and their implications. Losses due to disease—whether by slow continuous attrition or by sudden catastrophic epizootics—are by now all too familiar problems that confront aquaculture ventures. The technology to reduce the impact of disease is developing, but newer and often more difficult problems emerge to replace the solved (or at least somewhat understood) disease problems of yesterday.

Looking generally at the history of disease in fresh-water aquaculture in the United States and Europe, attention has been and continues to be on salmonids and catfish. Much current emphasis is focused on virus diseases of fresh-water fishes, whereas a few decades ago the bacterial diseases dominated. At a 1972 FAO-sponsored symposium on communicable diseases of fish, about 80% of the time and discussion was occupied with viruses—producing an impressive array of present-day problems: (1) Viral Hemorrhagic Septicemia (VHS) of trout in Europe, but not in United States; (2) Infectious Hematopoetic Necrosis (IHN) of rainbow trout and salmon in United States, but not in Europe; (3) Ulcerative Dermal Necrosis (UDN) of salmon in western Europe, especially in the British Isles; (4) Infectious Dropsy Complex of carp in Europe, in which a dominant viral role is emerging; and (5) Swim Bladder Disease of carp, which moved westward out of the Soviet Union and reached the Federal Republic of Germany a few years ago. It is presumed to be of viral etiology. Furunculosis, lymphocystis and whirling disease of salmonids were also considered, but the relatively recently recognized viral infections clearly occupied center stage in this consideration of fresh-water aquaculture disease problems.

Since intensive marine and estuarine culture has a shorter history than fresh-water culture, the state of knowledge about marine diseases is correspondingly less advanced. Major disease-caused mortalities have occurred in cultured oyster populations in the United States and elsewhere in the world (Sindermann, 1976), and disease has emerged as a deterrent to successful culture of shrimp and salmon in salt water and continues to be a problem in Japanese marine fish culture (Fryer *et al.*, 1976; Johnson, 1975). Knowledge about marine diseases has advanced rapidly within the past several decades.

In attempting to describe the role of disease in aquaculture, there are many aspects that could occupy our complete attention. Since this paper is designed to present an overview of the present status of information about disease and disease control in fish and shellfish aquaculture, the following categories should provide a reasonably comprehensive structure:

1. Disease and environmental stress;
2. Disease control, including immunology and vaccine development, and larval disease control;
3. Non-infectious diseases;
4. Effects of introductions of non-indigenous species; and
5. Assessment of the significance of disease in culture.

The consideration of each category must be brief, to keep the manuscript at a realistic size, but it should be clear that the subject matter area is a dynamic and rapidly-expanding one, with new research findings being reported constantly.

Disease and Environmental stress

One of the exciting, complex, and often frustrating aspects of presentday aquatic animal disease research is that concerned with environmental influences—the examination and definition of environmental stress as a major determinant of disease. This is probably the most significant concept involved in understanding the role of disease in aquaculture populations.

It has long been recognized that non-optimum conditions in culture operations, such as high temperatures, low oxygen, inadequate diets, and presence of metabolites in closed systems, could enhance effects of known pathogens and encourage cativities of facultative pathogens. Stress results from any departure from optimum conditions for a much larger list of factors, including temperature, salinity, oxygen, shelter, space, substrate, light, water flow, population density, competition, predation, nutrition, presence of toxins, and chemical pollutions. Some factors are biological, and some physical or chemical; single factors may dominate at any point in time. Some are directly lethal, others can lead to debilitation, physiological malfunction, or morphological abnormalities, all of which can render individuals more vulnerable to effects of other factors.

Stress in individuals can and will of course be reflected in changes in populations—either short-term or long-term, and either dramatic or subtle—affecting survival, growth and reproduction, and hence expansion or contraction of the population. However, attempts to quantify the effects of stresses often lead to some frustration. Most culture environments impose varying intensities of stress on the wild stocks or descendents of wild stocks that are cultured; the achievement of close-to-optimum conditions is a goal that is rarely reached.

It would be reasonable to attempt to define stress—a significant if somewhat elusive concept in biology, which, like any concept, can be misunderstood or misinterpreted. Stress as a major factor in human disorders was first enunciated by Hans Selye, a Canadian, in 1936, and the concept of stress, as it applies to humans, included three phases, as seen in Fig. 1. A redescription of the concept, as it may apply to any organism or population is presented in Fig. 2.

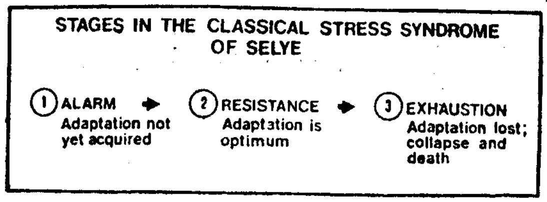

Fig. 1. Phases of the stress syndrome in human (Selye's original concept).

Selye (1950, 1952) defined stress as 'The sum of all the physiological responses by which an animal tries to maintain or reestablish a normal metabolism in the face of a physical or chemical force.' Others have proposed many modifications of this definition.

Brett (1958) defined stress as 'A state produced by any environmental or other factor which extends the adaptive responses of an animal beyond the normal range, or which disturbs the normal functioning to such an extent that, in either case, the chances of survival are significantly reduced.' Another definition which clearly identifies stress as the product and not the cause of homeostatic change is that of Esch *et al.* (1975): 'Stress is the effect of any force which tends to extend any homeostatic or stabilizing process beyond its normal limit, at any level of biological organization.'

All of these definitions are vaguely unsatisfying, but in its broadest sense *stress represents the sum of morphological, physiological, biochemical, and behavioral changes in individuals which result from actions of stressors.*' The effects of stress are often expressed in phenomena that collectively are called 'disease'—either infectious or non-infectious. Infectious diseases may result from lowered resistance to frank pathogens, from invasion of damaged tissue by facultative (secondary) pathogens, or by proliferation of latent infections. Non-infectious diseases may result from early genetic damage, or from chemical modification of tissues, leading to skeletal anomalies and tumors. Infectious disease can be a cause as well as a consequence of stress. The infectious agent—the pathogen—can act as stressor, producing changes in the host which in the extreme may result in death. What is referred to as disease in culture operations is often a consequence of one or more of such marginal environmental factors: nutrition, water quality, oxygen, temperature, salinity, and high bacterial populations.

Dr. Snieszko of the Bureau of Sport Fisherias and Wildlife, in an excellent article in the Journal of Fish Biology (Snieszko, 1974) summarized present knowledge of the relationships between environmental stress and fish diseases. One association which he mentioned, and which should be further emphasized, is the emerging information about population explosions of bacteria of the *Vibrio-Pseudomonas -Aeromonas* group. Suggestions of these increases exist in reports from marine as well as fresh water. High population densities of such heterotrophic and potentially pathogenic microorganisms, caused in part by high levels of organic material in the aquatic environment, can increase infection pressure on aquatic animals of all kinds, animals which are often being subjected simultaneously to other respiratory and chemical stresses in degraded environments.

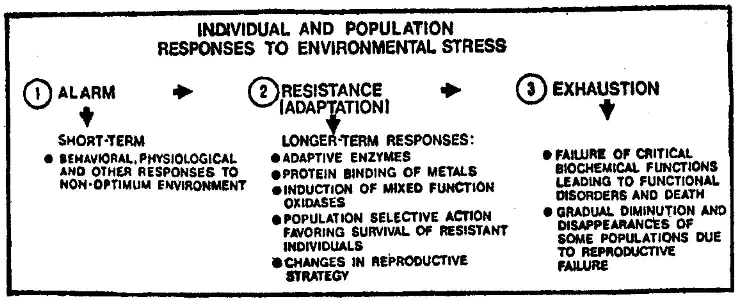

Fig. 2. Generalization of the stress phenomenon.

An understanding and appreciation of the role of environmental stress in the phenomenon that we call disease is of great significance in the culture environment. In considering problems of stress and disease in aquaculture, it is important to distinguish between what we can label *primary pathogens*, such as *Aerococcus viridans* in lobsters, which can kill even when other environmental factors are reasonably adequate, and *facultative* or *opportunistic* pathogens such as vibrios, pseudomonads, and aeromonads which kill when other physiological or environmental factors are poor or marginal.

Disease Control in Culture

Disease control has emerged as an extremely important component of culture technology—in fact it can be a critical and at times determining factor in the viability of aquaculture enterprises. Because of its obvious significance, disease control will be considered here in three aspects: chemical prophylaxis and treatment, immunology and vaccine development, and control of larval diseases.

Chemical prophylaxis and treatment

Chemical prophylactic and treatment methods particularly for salmonid fishes, have been elaborated during the past half century. An extensive technology of disease control necessarily paralleled the development of fish culture in fresh water. Beginning with the simpler chemical measures (formalin, copper sulfide, malachite green), treatments have progressed through the sulfa drugs to antibiotics and the nitrofurans. With all this chemistry, we often lose sight of the fact that control of disease should logically concentrate on prophylaxis rather than treatment—and prophylaxis must emphasize adequate water quality and nutrition, as well as reduction of as many stresses on cultured populations as possible. Chemical prophylaxis (and probably chemotherapy) Should be considered as 'last resort' methods in disease control, as was pointed out by Hermans (1970).

The technology of prophylaxis and treatment of diseases in marine aquaculture is extremely incomplete. Some of the remedies developed for control of fresh-water fish diseases can be adapted for use with marine fish, but the whole field of marine invertebrate disease control requires extensive experimentation. Disease control should be more feasible in controlled (intensive) culture than in open (extensive) culture, since under controlled conditions it is possible to manipulate water temperature and quality, to observe early indications of disease, and to eliminate parasites with complex life cycles. However, in controlled intensive culture, animals must be crowded and fed on artificial diets, which may result in deficiency diseases. Also, bacterial populations in the system must be monitored closely.

Disease control in aquaculture populations depends on a complex of three factors: diagnosis, preventive measures and treatment.

i. Correct *diagnosis* (including understanding of the life cycle and ecology of the pathogen) is obviously a critical step in and control program, and is often difficult for marine pathogens, about which relatively little is known.

ii. *Preventive measures*, the core of disease control programs, include the following: (*a*) maintenance of water quality; (*b*) reduction in other forms of environmental stress (low O_2, temperature extremes, buildup of waste products); (*c*) adequate nutrition; (*d*) development of disease resistant stocks; (*e*) vaccine development for immunological protection; (*f*) environmental manipulation (e.g., culture of oysters in salinities below that at which a particular pathogen will survive); (*g*) regulations to prevent transfer of pathogens from one host population to another—nationally or internationally; and (*h*) chemical prophylaxis.

iii. *Treatment* of disease in aquaculture is usually in the form of chemotherapy, possibly combined with some of preventive measures listed above.

Chemicals added to culture systems for disease control may perform two important positive functions: (1) they may reduce or eliminate pathogens, and (2) they may reduce or control populations of heterotrophic microorganisms which may act as facultative pathogens of animals under stress. Such chemicals may, on the other hand, cause problems in culture systems: (1) they may have negative effects on biological filters in controlled recirculated systems — particularly on nitrifying bacteria; (2) they may have negative effects on algal food, or on algae present in fish larval rearing tanks ; and (3) they may leave undesirable or harmful residues in cultured animals.

A wide range of chemicals has been used to control aquatic diseases — mostly in fresh water, but lately in salt water as well. The sulfas had earlier and continuing utility, with the various antibiotics being applied soon after. At present there is much interest in the nitrofurans — a class of chemotherapeutics first developed by the Japanese against bacterial fish diseases. The development of drug resistance has been and continues to be a significant problem.

One very important general point which must be kept clearly in mind when considering chemical methods of disease control is the restriction on use of chemicals to treat animals being raised for food. Such restrictions vary from country to country, of course. At present, for example, only salt, acetic and sulfamerazine are approved by the United States Food and Drug Administration for use on all food fish, while oxytetracycline is restricted to use with trout, salmon, and catfish. This means that such common and useful substances as formalin, furanace, copper sulfate, acriflavin, and potassium permanganate may not be used legally at present in the United States in treatment of species destined for human consumption.

It should also be pointed out that some chemicals (such as malachite green) may be carcinogenic, or may cause other damage to humans who handle the compounds. Some potentially harmful chemicals may actually be used, even though they are not cleared, and use of such chemicals may leave persistent residues in the harvested product destined for human consumption. Other chemicals may affect food chain organisms in the natural environment ; their widespread use should be discouraged. Accelerated clearance of chemicals, or publication of definitive data on their harmful effect(s) should have high national priority.

Disease control measures must include proper diagnosis, suitable prophylactic measures (such as strict maintenance of water quality) and chemotherapeutic methods when needed. Available technology is fair for fresh-water diseases, exclusive of viruses, but poor for marine diseases.

Immunology and vaccine development

In addition to chemical prophylaxis and treatment, an important aspect of disease control, both for fish and shellfish, is that of augmentation of the internal defense mechanisms of the animal. The immunological responses of fish generally parallel those of terrestrial vertebrates, including phagocytosis and the elaboration of specific immunoglobulin antibodies. This fact has been used in prophylactic immunization of several species of fresh-water fishes, and more recently in attempts to immunize salt-water held salmon against vibrio and other bacterial infections (Fryer *et al.*, 1976 ; Cisar and Fryer, 1974). High antibody titers can be obtained by intraperitoneal injection of killed bacteria, and some protection of experimental animals is afforded by oral immunization. It may be that early prophylactic immunization using a combination of injected and oral vaccines — plus antibiotics added to diets when disease signs appear — may be methods of choice with salmon vibrio disease.

Among the invertebrates, response to infection seems to be less specific and largely cellular, although recent work with American lobsters (Paterson and Stewart, 1974) has demonstrated increased phagocytic activity, with a suggestion that vaccines prepared from avirulent strains of the pathogen *Aerococcus viridans* produced a limited degree of resistance to the disease (Gaffkaemia) which it causes (Fig. 3). Additionally, injections of antibiotic (Vancomycin) plus virulent bacteria provided short-term protection. In other studies, increased bactericidal activity, following injection

Fig. 3. *Aerococcus viridans* in haemolymph smears from American lobster *Homarus americanus*. Note phagocytized and free pathogens (from Sindermann, 1977).

of bacterial antigens, was found to exist in spiny lobsters (Acton *et al.*, 1969).

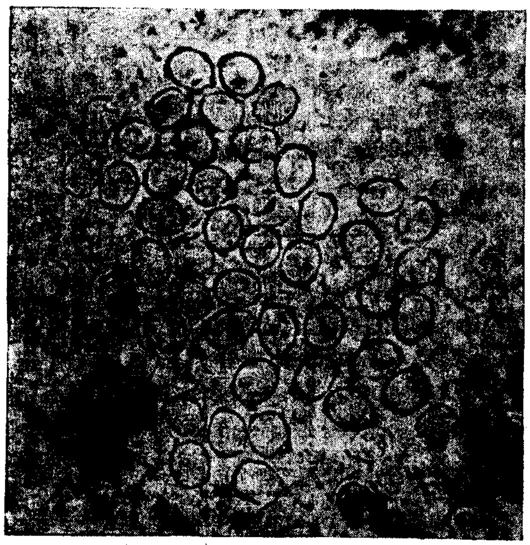

Fig. 4. Spores of *Minchinia nelsoni* in digestive gland tubules of eastern oyster *Crassostrea virginica* (from Sindermann, 1977).

Development of disease resistance in populations of oysters exposed to epizootic levels of particular pathogens is suggested by recent observations. A high degree of natural selection for disease resistance in oyster populations exposed to the protozoan *Minchinia nelsoni* (Fig. 4) has been reported recently by Andrews and Frierman (1974). An unknown pathogen responsible for extensive oyster mortalities (1916-1959) in the Gulf of Saint Lawrence, Canada, has also resulted in selection for disease resistance, in that oysters from other areas die when introduced, whereas native oysters do not die at present.

Since we now have several examples in invertebrates (oysters) where severe natural selection during epizootics seems to have produced resistance in surviving populations, attempts are now underway at several research institutions in the United States to do this experimentally with oysters, and the objective of resistant stocks is a logical one for any genetic modification program with controlled reproduction.

Control of larval diseases

An ultimate requirement of aquaculture is control of the entire life cycle of the animal of interest. This is true of animals reared in controlled or open systems — and includes spawning, hatching, and larval development under artificial conditions. Larvae are particularly vulnerable to diseases, but comparatively little attention has been directed to larval diseases until quite recently. We have finally moved beyond the stage that a well-known United States fresh-water biologist, Fred Meyer, described as the 'Arkansas Dwindles' — where larval populations just dwindled away, and we merely shrugged our shoulders and started over. We have now recognized a number of microbial diseases of fish, mollusc, and crustacean larvae and are trying to develop control methods (control of water quality is still the most important method).

A basic problem seems to be that we often lose sight of individual larvae, and think only of the larva population as a whole — probably since any treatment of larval diseases must be mass rather than individual treatment. It has been expressed recently by at least some of those developing commercial aquaculture, that the 'best solution to larval disease problems is to discard the entire culture and start anew', since so little time and money has been invested in that culture, as compared to animals approaching market size. This negative approach to larval disease control ignores at least two critical points: (1) unavailability of larvae at a particular time can dislocate the entire aquaculture production system; and (2) sublethal abnormalities and disabilities, both physiological and morphological, may be produced by disease in larval stages, and may be carried through to juvenile and adult stages — often resulting in less than optimum growth rates and a less desirable product.

Diseases of larvae are often directly related to water quality and nutrition, so effective prophylactic measures should include sterilization of water, careful attention to pH and salinity, and proper feeding levels. Molluscan larvae are subject to vibrio and other microbial infections (Fig. 5), which may produce mass moralities in only a few hours from onset of disease signs. Crustacean larvae are also affected by bacterial diseases, but fungi seem to be very important, judging from recent reports from shrimp and lobster aquaculture efforts. Additionally, epibionts — plant and animal, particularly stalked ciliates and filamentous bacteria — can have pronounced negative effects on larvae when water quality is poor.

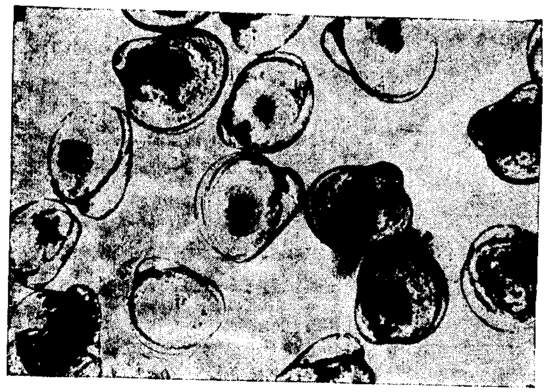

Fig. 5. *Vibrio* in molluscan larvae. Note dead and dying larvae and typical 'Swarming' of bacteria (from Sindermann, 1977).

NON-INFECTIOUS DISEASES

Thus far this paper has emphasized infectious diseases, usually caused by microbial pathogens. There are of course many diseases of non-infectious etiology as well, and we are beginning to pay more attention to such non-infectious diseases in aquaculture — to such things as genetic anomalies and death of larvae, and to skeletal and other growth abnormalities — which fall within the broad definition of disease. We are also beginning to separate and identify those diseases that seem related to stress from those of clearly infectious origin. We are even beginning to consider those disabilities that may be related to environmental pollution and inadequate nutrition.

Effects of pollution, whether resulting from build up of toxic metabolic products within the culture system or from introduction of contaminants from outside the system, can be severe. Stress from pollutants may be expressed in a number of ways, including diminished reproductive activities ; damage to genetic material of the egg or embryo with resulting mortality or abnormal development ; direct chemical damage to cell membranes or tissues ; modification of physiological and biochemical reactions ; changes in behaviour, often due to chemical damage to sensory equipment ; increased infection pressure from faculative microbial pathogens ; and reduced resistance to infection. Sublethal effects such as spawning failure, poor survival of larvae, larval setting failure in the case of shellfish, reduced growth rates, and increased vulnerability to other environmental limiting factors can have significant effects that may be less apparent. Greater understanding of such sublethal effects is needed to assess fully the influence of any single stress factor on aquaculture production.

Early life history stages of marine animals are usually (but not always) more susceptible to chemical stress than later stages. Effects may be obvious, resulting in death, or less obvious — such as genetic damage which may not be expressed until later developmental stages (as abnormalities in structure or function). Genetic damage to sex products, embroys, or larvae may be an important and as yet poorly understood consequence of chemical contamination of culture waters.

Nutritional deficiency diseases have received much attention in freshwater hatcheries, and reasonably adequate diets have been developed by trial and error over decades. Much of marine aquaculture is still hampered by the absence of complete artificial diets, and a number of apparent deficiency diseases have been recognized. With penaeid shrimps, for example, ascorbic acid deficient diets result in weakening and mortality of juveniles in a syndrome called ' black death ' (Lightner, 1977). With pompano (*Trachinotus carolinus*) reared in salt-water cages, a diet deficient in animal protein produces liver degeneration and an edematous ' dropsy ' condition (Fig. 6), which can be fatal if the diet is not improved.

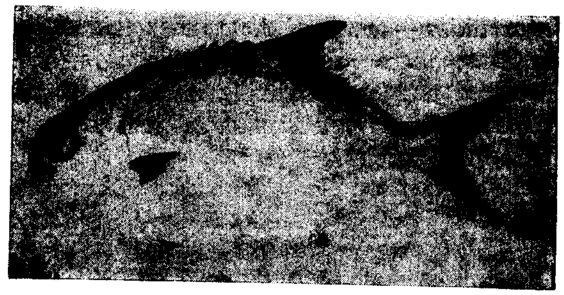

Fig. 6. Pompano *Trachinotus carolinus* from cage culture showing ' dropsy ' condition (from Sindermann, 1977).

Effects of Introductions of Non-indigenous Species

Aquaculture enterprises have in the past and undoubtedly will continue to depend in part on introductions of non-indigenous species as animals of choice for culture production. Such introductions pose potential disease problems, especially when they take place in open system culture.

Introduced species may be susceptible to endemic pathogens, parasites, commensals and predators in new grow-out areas, and the native species may be susceptible to pathogens, parasites, commensals and predators imported with the introduced species.

Probably the best example of the realities of disease problems caused by introductions is that of the Japanese seed oysters brought to the United States west coast. A copepod parasite *Mytilicola* (Fig. 7), was introduced with the Japanese oysters and affected stocks of native oysters (*Ostrea lurida*). Oyster drills were also introduced. A bacterial disease, resulting in ' focal necrosis ' of oyster tissues was also introduced, as far as can be determined. Disease problems in oysters on the coast of France may have been exacerbated in recent years by massive introductions of *Crassostrea angulata* from other European countries and *Crassostrea gigas* from Japan. Mortalities — many of them unexplained but at least some caused by pathogens — have occurred and are occurring in native *Ostrea edulis*, in *Crassostrea angulata*, as well as in the introduced species.

is, however, little direct evidence yet of significant harmful effects on native marine species resulting from introductions of exotic pathogens (with the possible exception of *Mitilicola* in oysters). However, marine pathology has a short history, and effects on native species may not have been observed and reported — even if they occurred in the past. Even now, with recent large-scale intercontinental movements of oysters from Japan and Canada to France, and recent extensive disease-caused mortalities in native populations, it is difficult to determine which pathogens may have been enzootic, but unobserved in the recipient area and which ones may have been introduced. Additionally, the possible effects of introduced pathogens on unrelated host species in the recipient area has received very little attention,

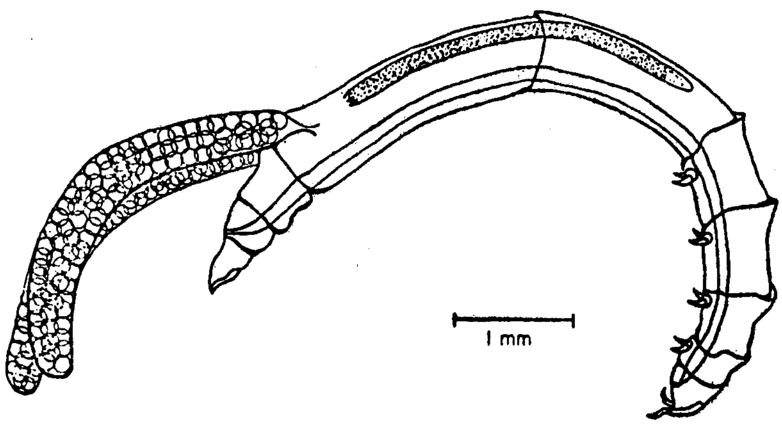

Fig. 7. *Mytilicola orientalis* in digestive tract of Pacific oyster *Crassostrea gigas* (from Sindermann, 1977).

Another example of introduction of a serious disease in freshwater is the transfer of ' whirling disease ' of salmonids, caused by the protozoan *Myxosoma cerebralis*, from Europe to the Unites States — with subsequent major economic losses in some states.

Looking at these and other examples, it is clear that harmful diseases of fresh-water fishes have been introduced as a result of shipment of live fish or fresh fish products. There

and would be extremely difficult to predict, even with attention from marine pathologists.

An important concept in these and all introductions is that oı ' critical mass '. I believe that this concept is too often overlooked in considerations of introductions.

Small introductions — a few hundred individuals or less — are made much more frequently than we know, either deliberately or accidentally. Isolated, small-scale, one-time only, introductions seem less likely to cause major disease problems, based on present knowledge, However, the long-term risk must be considered ; it may take decades for the development of the critical mass of infective bodies — the pathogen population.

It must be pointed out that the degree of virulence can help determine the critical mass of the introduction (containing a potential pathogen) required before a disease problem presents itself in a susceptible native population.

Another concept that must be stressed is the degree of risk involved in introductions. Those who make decisions about introductions must be told frankly about the adequacy or inadequacy of the data base on which estimations of risk of epizootics are made. They must also know that risk assessment, even with reasonable data available, is still a some-what subjective matter, subject to large error. In most instances, available information about specific pathogens simply does not permit objective assessment of risk. Occasional monumental failures and massive miscalculations of risk will occur and should be anticipated despite the best precautions.

A final concept — less acceptable to some countries — is that wherever possible, great efforts should be made toward the development of aquaculture of endemic species instead of imports. With modern techniques of hatchery production and selective breeding there should be progressively less demand for introductions of non-indigenous species on economic grounds.

Despite all this, transfers and introductions of non-native species will probably continue, so a plan of action should be developed to limit risks of disease (Fig. 8). Such a plan should include (but not necessarily be limited to) the following :

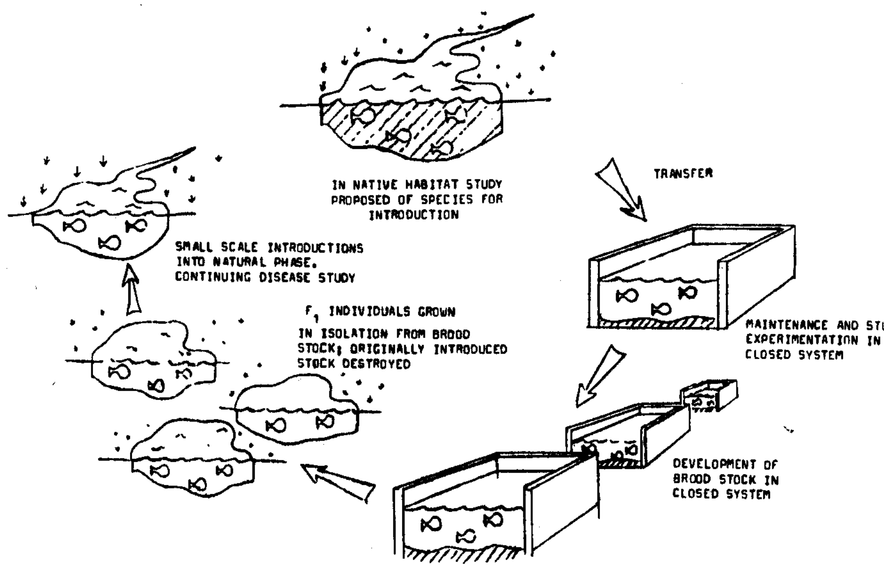

Fig. 8. Proposed sequence of steps in introducing non-indigenous species.

i. Before any attempt at introduction, a detailed disease study, concentrating on possible microbial diseases, should be carried out where the species is native. This must be a combined microbiological, histopathological, and parasitological study.

ii. The species to be introduced should be examined in closed or controlled systems for an extended period — up to a year — to see if any unique disease problems emerge.

iii. Brood stocks should be maintained in closed or controlled systems; larvae should be removed from any contact with brood stock; and only the offspring should be permitted to be placed in open waters. Brood stocks should then be developed from these offspring, and the original stocks destroyed. (It might be noted here that disease can become a major problem in maintenance of brood stock — whether introduced or not — and an important consideration should be preventing transmission to eggs or larvae).

iv. Initial introductions of offspring of foreign species in open waters should be small ones, to make manageable any problems which emerge — but should be done in several areas, since environmental conditions may not be suitable in all areas.

Despite the present absence of strong evidence, introductions of non-indigenous marine species without adequate microbiological, histopathological and parasitological examinations can introduce disease problems into marine aquaculture areas. As an example, I would point out the potential horrors of importing oysters (*Crassostrea virginica*) from North America. This species occurs on the east coast of North America discontinuously from Prince Edward Island to Mexico. With very few local exceptions, at least one serious microbial disease is present in populations that occur along this entire range, and new extensions of known diseases are frequently reported. All of these diseases have a clear history of epizootic outbreaks, with resultant mortalities.

Assessment of the Significance of Disease in Aquaculture

Most of us as scientists are convinced of the importance of our own special area of research to the well-being of the broader universe — to the extent that we sometimes lose touch with reality. Those of us concerned with aquaculture diseases have been accused of doing this with disease in marine culture. In fact, at a recent regional symposium in the United States, a well-informed aquaculturist made the claim that 'it was not disease *per se* that was acting as a deterrent to successful culture, but rather the *fear* of disease outbreaks and subsequent economic disaster that was discouraging investment.'

Where is reality here? What has been the experience with species which have been cultured? How important is disease to success or failure? Some of the experience in the western hemisphere with marine and anadromous species can be summarized by species or groups of species as follows:

i. *Penaeid shrimp diseases*

Principally because of the extensive research, development, and production activity in culture of shrimps of the genus *Penaeus*, much information about diseases and their control has become available. At present, nine diseases — one viral, three bacterial, two fungal and three protozoal — seem to constitute reasonable entities, with several others of unknown or uncertain etiology. An apparent problem is the proper recognition of what can be called generalized disease signs, such as black gills, which may result from a number of causes, infectious and non-infectious. Some of the diseases described seem clearly related to unsatisfactory water quality.

ii. *Malaysian prawn diseases*

Several species of freshwater prawns, particularly the giant Malaysian prawn *Macro-*

brachium rosenbergii, have been subjects of intensive culture efforts in the United States and elsewhere during the past decade. Because spawning and larval development occur in saline waters, these animals logically become part of marine aquaculture.

Thus far, disease problems with *Macrobrachium* culture have been relatively minor, and seem to result largely from poor water quality or other stresses characteristic of artificial environments.

iii. *Lobster diseases*

Natural production of the American lobster *Homarus americanus*, has been unable to meet market demand, despite continuously increasing prices. Several major multidisciplinary research and development projects exist in the United States and in Canada, and much information has accumulated about a number of lobster diseases. Seven have been recognized as being of significance in culture systems, three bacterial, three fungal, and one protozoal.

iv. *Blue crab diseases*

Annual production of blue crabs *Callinectes sapidus*, on the East and Gulf Coasts of the United States is high, but variable from year to year. Market demand makes it a desirable species for culture and some limited attempts are being made. The recognized diseases of blue crabs of significance to culture operations have increased in number rapidly. At present, ten diseases — two viral, two bacterial, one fungal, and five protozoal — have been described.

v. *Oyster diseases*

Aquaculture of oysters in the United States emphasizes two species — the American oyster, *Crassostrea virginica*, and the Pacific oyster *Crassostrea gigas*. There is some very limited culture of the Olympia oyster *Ostrea lurida*, and the European oyster *Ostrea edulis*. Oyster hatcheries now exist on both coasts, but their contribution to commercial production — when compared to natural set — is small.

Hatchery diseases recognized so far are bacterial and fungal, and seem related to water quality. The most important diseases in growout areas are fungal and protozoal.

vi. *Clam diseases*

Hatching, rearing and limited production of hard-shell clams *Mercenaria mercenaria*, exists on a small scale on the United States east coast. Other species, such as the east coast surf clam *Spisula solidissima*, and several west coast clams have attracted some research attention, but at present almost all clam production is from natural beds. Only two diseases — bacillary necrosis and larval mycosis — have been clearly associated with larval mortalities, although a number of bacteria have been shown to have deleterious effects.

vii. *Pacific salmon diseases*

Commercial-scale rearing of Pacific salmon (*Oncorhynchus* spp.) in salt water has been undertaken on both coasts of the United States in the past several years. Salt-water rearing has had to content with some of the classic diseases of fresh-water salmon hatcheries — farunculosis and kidney disease — but also with severe problems with halophilic vibrios, particularly *Vibrio anguillarum*. For several years the continued survival of salt water rearing attempts with salmon seemed to hinge on solution to the vibrio problem. Some successful control methods have been developed, but the problem still exists. At present, three bacterial infections are of significance in salt-water culture of salmon — vibriosis, funrunculosis and kidney disease. Other disases problems exist, but they seem to be of lesser importance at present.

Faced with the evidence accumulated thus far, it seems reasonable to conclude that there is a significance and continuing problem with disease in aquaculture. It may not always assume the overwhelming aspects of epizootics (in fact it usually doesn't) but it must rank among the more important factors to be considered in production systems (Sindermann, 1977).

Some data exist, particularly for fresh-water species, about the costs of disease control. In United States federal salmonid fish hatcheries, disease control costs have been estimated at 10-15% of total production costs, while several state hatchery systems have been estimated such costs at 20-30%. Mortalities due to disease, and the necessity for disease control measures, have been estimated at 25% of commercial production costs for rainbow trout, 10-25% for channel catfish, and 20-30% for shrimp.

Conclusions

Aquaculture is a growing factor in worldfish and shellfish production — amounting to an estimated 6 million tons per year (or 10% of total world production of fish and shellfish). Marine aquaculture, particularly of fish, is of more recent origin, but holds great promise. Disease has been and is a significant deterrent to successful marine aquaculture, as it has been for fresh water aquaculture, but the technology of disease control is developing slowly.

Disease effects on cultured organisms can cover an entire spectrum from epizootics with mass mortalities to no observable effects on cultured populations. Where on this spectrum the disease will be at any moment depends on dynamic interactions among the host, the pathogen, and the culture environment.

Consideration of aquaculture as it now exists seems to justify several generalizations about diseases :

1. Disease in cultured populations assumes even greater significance then it does in natural populations for a number of reasons, including the following : (*a*) cultivated animals often are more crowded than those in the natural habitat, which facilitates transmission of pathogens and parasites ; (*b*) shellfish are often cultivated in areas where natural populations did not exist previously — their absence under natural conditions suggests some environmental limiting factor or factors ; (*c*) some culture still depends largely on capture and impoundment of juveniles which may be slightly injured during capture, or which may be already infected by certain pathogens ; and (*d*) the nutrition of cultivated populations may be deficient.

2. Transfers and introductions of species for aquaculture purposes can increase disease problems in cultivated populations. Susceptible animals may be introduced into areas in which particular diseases are enzootic or epizootic, or new diseases may be introduced when transfers from other geographic areas are made.

Disease is now and will continue to be a significant problem in marine aquaculture. At times it may determine the success or failure of a venture. Expansion of marine fish and shellfish culture has been and will be accompanied by increases in mortalities due to disease. It behooves us therefore to learn as much as we can about the diseases which can exert severe limitations on the success of marine aquaculture.

3. Diseases caused by vibrios have already assumed great importance among cultivated marine fish and shellfish populations. In fact, the emergent role of halophilic vibrios is one of the most exciting present aspects of disease studies in mariculture. The past few years have seen some elucidation of the identity of the pathogens involved, but the picture is still murky. The etiological agent (or agents) of ulcer disease in Japanese fish was recently described as having characteristics of *V. parahemolyticus* (which causes human 'summer sickness') and also *V. anguillarum* (long known

to cause red disease of eels). Krantz and coworkers (1969) found *V. parahemolyticus* in Chesapeake Bay blue crabs, and postulated that the vibrio is a pathogen of crabs.

(4) Pathogenic roles in cultivated populations of marine fish and shellfish have been assumed by certain organisms that are often rare and innocuous parasites in natural populations. Many of these organisms are the same ones known as pathogens in marine aquaria. Frank virulent pathogens are usually associated with epizootics in natural populations, whereas facultative pathogens tend to emerge as causes of epizootics in culture populations. Such facultative organisms are often considered as benign or rare in wild populations.

(5) The larger animal parasites, especially those with complex like cycles, are usually of relatively minor importance in cultivated marine populations, but those with a single host — particularly the microbial parasites, with direct water-borne transmission and short generation periods — are of great importance.

(6) Molluscan shellfish culture (at present based on the most advanced marine aquacultural practices) has repeatedly experienced mass mortalities from outbreaks of epizootic disease. Some control measures are available, but the extent of knowledge of the diseases involved is still so limited that effective control (particularly in natural waters) is not yet an actuality.

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FIN-FISH CULTURE *

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INTRODUCTION

THE TOTAL yield from wild stocks of marine species is still increasing but at a progressively reduced rate. With the declaration of the Exclusive Economic zones and consequent realignment of marine fishing activities all over the world, a greater awareness has been created for production of aquatic food, particularly animal protein food.

Aquaculture is an age old practice in some countries but in others, it is of a very recent origin. It has developed from small-scale fish farming to large aquaculture industries. The evolution of modern aquaculture involves improvements to environment, large scale fish farming and sophisticated systems of intensive culture for various organisms.

World production through aquaculture in 1975 was estimated to be over 6 million tons and has been projected to be 12 million tons by 1985. In 1977, the provisional figures indicated a total production of 7 million tons, of which about 3 million tons are derived from mariculture. Within the production through mariculture, the share of marine fin-fish was about one million tons. While the cost of fishing, the law of the sea and the need to find employment for excess fishermen provided the necessary incentives for aquaculture development, the high costs of feeds, shortage of fertilizers, pollution problems and indiscriminate application of certain environmental protection regulations reduced the pace of aquaculture development.

The present area under aquaculture is estimated to be 3 to 4 million hectares with a production of few kilograms to about 20 tons per hectare per annum. It is expected that there could be a ten-told increase in the area and 2 to 3 fold increase in yield within a short time, provided necessary investments are forthcoming. The present day fish farming has expanded in area, methods and technology.

MAJOR GROUPS/SPECIES

Fish are raised in freshwaters (warm and cold), brackishwaters and in the sea. The species include the catadromous, anadromus and other marine species which spend their entire life-cycle in salt water. Purely marine species are also raised in brackishwater and purely fresh water species in low saline waters. Although some impressive culture of a few species of fishes has been established, the scope has been limited with emphasis only on 'luxury' items. Aquaculture is in its infancy, despite tremendous research efforts and investments in recent years.

The following are the major groups/species of fishes being cultured in several parts of the world along with rates of production.

I. Mullets
   i. *Isreal* (Commercial): 512 kg/ha/109 days-Polyculture with *Tilapia*.

* Keynote address delivered at the Symposium.

ii. *Italy* (Commercial) 200 kg/ha/year—Valli culture with gilthead bream and bass.

iii. *Hong Kong* (intensive, with supplementary feeding): 2,500-3,500 kg/ha/growing season (?).

iv. *India* (Commercial)

(*a*) *Bheris* (W. Bengal): 111.4-168.2 kg/ha of mullets and prawns.

(*b*) Paddy fields (W. Bengal): 62% of production is mullets. India (experimental, Cochin farm, early forties): 4,090-4, 771.8 kg/ha/2 years (?): Production rates about 1000 nos. of fish/ha/ ?

v. *Philippines* (Commercial): 336 kg/ha/year—Polyculture.

vi. *U.A.R.* (experimental): 350 kg/ha/year-polyculture.

II. *Chanos chanos*

i. *Indonesia* (Commercial).

a. Traditional method : 50-500 ka/ha.

b. 3 months rotation method: 5,000 kg/ha

ii. *Philippines i*

a. Traditional ponds: 67 kg/ha

b. Lake pens: 4 tonnes/year.

iii. Taiwan: 2,000 kg/ha/year—estuarine ponds, pens

v. *India* (experimental):

a. Sandy, low productive substratum: 457 kg/ha/year (Mandapam)

b. Clayey locality: 857 kg/ha/year (Tuticorin).

III. Eels

i. *Japan*

a. Still waters: 6, 120 kg/ha/year

b. Running water: 25,360 kg/ha/year

ii. *France*

10-12 tonnes/ha.

iii. *Italy*

3 kg m^3/year

iv. Yellow tail

Japan i 20-25 tonnes/ha/year.

V. *Chrysophrys*

Japan i 6 tonnes/ha/year.

Culture Systems

The culture systems include the very extensive pond cultures of milkfish, shrimp in the trap systems, tilapia in brackishwater and freshwater, the milkfish and seabream in freshwater ponds and cage culture of fish in enclosures at sea. The culture systems have expanded from simple ponds to running water systems or raceways and enclosure systems ranging from rafts and cages (floating and sugmerbed) to framing fjords. The systems include culture of forage and predator fish. They may be extensive or intensive cultures.

Source of Seed

The seed for culture purposes is collected from natural sources and controlled breeding is still in the experimental state. Production of fish per unit water area can be increased by the fuller utilization of spawn from the sea, development of efficient gear for capture of fry, detection of new fry grounds, improved techniques of growing seed in brackishwater farms, better methods of preparation of ponds, use of organic and inorganic fertilizers, stock manipulation, use of supplementary feed and use of pesticides.

For some species, eggs, fry and fingerlings can be obtained only from the sea. There may be considerable variations in the availability of the seed. In other cases, it is possible to raise and spawn adult fish. The modern practice of injecting hormones is used to obtain spawning and another method is to adjust photoperiod.

Artificial Feeds

A great variety of artificial feeds have been developed for maintaining fish in different systems and for increasing production. However, the very high cost of preparation, the conversion ratios, mortalities etc. have lead to production of only 'luxury' class fish in many cases. Improvements in this field are limited by the ability to secure various feed ingredients, mainly the fish meal, and their rising costs.

Sea Ranching

Referred to by a variety of names in different countries, sea ranching is the process of releasing hatchery reared animals into the sea for rearing and subsequent recapture of the adults upon their return to the point of release. Political and public decisions may restrict future development of this method.

Recent Advances

Important development in aquaculture in recent years include cage and enclosure/pen culture, polyculture, tilapia culture, shrimp and prawn farming, eel and oyster culture, recycling of water including utilization of waste heat. Special attention has been paid to controlled reproduction and formulation of artificial feeds. Hypophysation, manipulation of environmental parameters, use of prepared mammalian hormones in breeding procedures are major developments in the field. Other achievements include development of techniques of preservation of fish sperm, maintaining captive brood stock, find reliable sources of fish seed and acceleration of selective breeding. However, further studies are needed in the areas of standardization of dosage of hormones, precise methods of determining the state of maturity of the recipient fish and nutritional requirements in reproduction.

Since all energy is diverted to the maturation of gonads, the age at which the fish matures is a crucial factor in arresting growth. If maturity can be delayed or late maturing and sterile species can be bred, this may contribute to increase in production. Efforts have been made to manipulate chromosomes to produce sterile fish. Experiments are being conducted to prevent sexual maturity with the aid of hormones.

Intensive fish culture involves prevention of disease. Vaccination, use of antioxidants to prevent dietary diseases and application of antibiotics for control of bacterial diseases are some of the methods in vogue.

Techniques for rearing eggs and larvae of some species of marine fishes have been developed but commercial production of such species is yet to be achieved. Cross breeding of pelagic and demersal species may be a method to obtain economic yields from such fish.

Lacunae

It is often debated why it has been possible to culture fresh-water species extensively but not the marine species. Many economic reasons are suggested. The basic problem has been the mastery of the reproductive cycle of the species concerned. Unless there is mass production of fry of marine species, very little progress can be expected in mariculture. This is a challenge requiring great effort, imagination and investment.

Although fish farming has gained momentum, compilation of statistical data has been inadequate. Lack of skilled personnel, unwillingness or inability of producers to provide information, scattered location of production units, lack of interest to finance collection of data by some countries have all contributed to this scarcity.

COUNTRIES

Countrywise production rates of fin-fish are given below :

1. Mainland China : Of about 22 lakh tonnes of aquaculture production, about 2 lakh tonnes are believed to be from marine fin-fish culture. Believed to be mostly mullets, *Chanos* and eels, in estuarine and coastal ponds : mostly extensive.

2. U.S.S.R. : Of about 2.1 lakh tonnes of aquaculture production, about 1 lakh tonnes are believed to be from marine fin-fish culture. Believed to be mostly mullets and eels, in estuarine and coastal ponds ; mostly extensive cultivations.

3. Japan : Total mariculture fin-fish production—1.5 lakh tonnes annually.

   i. Yellow-tail (*Seriola quinqueradiata*) 81,000 tonnes annually ; coastal ponds, net enclosures, floating net cages ; intensive culture, rotation method ; artificial feeding.

   ii. Eels (*Anguilla japonica*), 25,000 tonnes annually ; inland ponds ; intensive culture ; artificial feeding.

   iii. Porgy (*Chrysophrys*), 1,000 tonnes annually ; net enclosures and floating net cages ; intensive culture ; artificial feeding.

   iv. Filefish (*Monacanthus*), 100 tonnes annually ; net enclosures and floating net cages ; intensive culture ; artificial feeding.

   v. Puffer (Fugu), 150 tonnes annually ; net enclosures and floating net cages ; intensive culture and artificial propogation ; artificial feeding.

   vi. *Caranx*, 70 tonnes annually ; net enclosures and floating net cages ; artificial feeding.

4. *Indonesia* : Total mariculture fin-fish production—1.5 lakh tonnes annually.

   i. Milkfish (*Chanos chanos*), 90,000 tonnes annually ; estuarine ponds ; extensive culture.

   ii. Mullets (*Mugil cephalus* etc.) 30,000 tonnes annually ; estuarine ponds ; extensive culture.

   iii. *Tilapia*, 10,000 to 20,000 tonnes annually ; estuarine ponds, extensive culture.

5. *Philippines* : Total mariculture fin-fish production—1.2 lakh tonnes annually.

   i. *Chanos chanos*, 1,00,000 tonnes, annually ; estuarine ponds, pens, net enclosures; extensive and intensive operations.

   ii. Mullets (*Mugil cephalus* etc.) 20,000 tonnes annually ; estuarine ponds, pens, net enclosures ; extensive and intensive.

6. *Thailand* : Total mariculture fin-fish production—50,000 tonnes annually.

   i. *Chanos chanos*, 30,000 tonnes ; estuarine ponds, pens, net enclosures ; extensive.

   ii. Mullets, 15,000 tonnes ; estuarine ponds, pens, etc. ; extensive.

7. *India* : Of the total aquaculture production of about 5 lakh tonnes, about 50,000 tonnes is estimated to be from mariculture fin-fish source ; about 25,000-30,000 tonnes are estimated to be from mullets (*Mugil cephalus, Liza macrolepis, L. dussumeri, Rhinomugil*

corsula. *L. tade*, etc.); 10,000-15,000 tonnes from *C. chanos*; 5,000-10,000 tonnes from *Lates calcarifer*.

8. U.S.A.—Total mariculture fin-fish production about 10,000 tonnes.

   i. Pompano (*Trachinotus*), 3,000 tonnes; coastal ponds and floating net cages; artificial feeding.

   ii. Salmonids (*Salmo*, *Oncorhynchus*), 5,000 tonnes; net enclosures and net cages; artificial feeding.

   iii. Mullets, 2,000 tonnes; coastal ponds; net enclosures; extensive.

9. *Italy:* Total mariculture fin-fish production about 10,000 tonnes.

   i. Mullets (*Mugil cephalus* etc.) 7,000 tonnes; estuarine ponds; extensive.

   ii. Eel (*Anguilla*), 3,000 tonnes; estuarine ponds; extensive.

10. *Israel:* Total production about 10,000 tonnes; mostly mullets; coastal ponds; intensive cultivation.

11. *Malaysia:* Total production about 7,000 tonnes; Chanos and mullets, estuarine ponds and pens; extensive culture.

12. *France:* Total production about 7,000 tonnes; mostly mullets and eel; estuarine ponds and net enclosures; extensive.

13. *Denmark:* Total production about7,000 tonnes; mostly salmonids (*Salmo*); floating net cages and fjords; intensive; artificial feeding.

14. *Norway:* Total production about 2,000 tonnes; salmonids (*Salmo*); floating net cages and fjords; intensive; artificial feeding.

15. *U.K.:* Total production about 2,000 tonnes; mostly flat-fishes (*solea*, *Pleuronectes*, *Scophthalmus*); lochs, net cages; heated waters; Intensive culture; Artificial feeding.

Trends in Production

In 1970, the total fish production through aquaculture was 2.6 million m.t. In 1975, it was nearly 6 million m.t. of which fin-fish contribution was estimated to be about 4 million m.t. The catch may be doubled by 1985 through application of modern technology which involves more efficient use of each unit of water area through greater concentration of number of fish, polyculture, more area brought under culture, feeding efficiency and breeding. For increasing production, greater amounts of fish meal have to be diverted for manufacture of artificial feeds. This involves better fish feed conversion. Increase in volume of cultured fish is related to production of forage fish relying on natural foods. All this means use of more water areas in those parts of world where fish culture is not commonly practiced to-day. African, Central and South American countries should intensify production.

Increase in production is dependent on marketing, price structure, political and legal considerations. Long term rights over water areas would benefit fish farmers. The rate of development and volume of production depends on the type and amount of assistance from Governments. Aquaculture would be affected by the ability to finance development, repayment provisions, infrastructure facilities including research, extension service, etc.

Economics

Since most of the coastal aquaculture operations are done on family basis appropriate records are not available on cost and earnings. However, they are known to be profitable.

Developing countries have somewhat been over enthusiastic by adopting highly sophisticated technology involving high cost and high degree of technology for achieving high production. These methods are suitable for rich countries where the earning and purchasing power of the people are high. Where large areas of land are available, labour is cheap and financial resources are poor. In such areas, less expensive techniques involving low cost should be tried though the production may be low.

FUTURE

The present production from aquaculture mainly comes from fresh or brackishwater ponds. It appears that large scale production of protein food in future must come from culture of marine species in the sea or in coastal waters. Competitive fish farming requires a definite frame work which includes fry production, feed supply, professional know-how, disease control, proper marketing etc. Thus, fish farming should become an integrated industry. Modern fish farming is inclined towards vertical integration. The farms are expected to be larger than at present.

Large scale fish farming requires an infrastructure comprised of systems for marketing, communication and supportive professional research. It needs financial backing of the government, Aquaculture is hard met to compete with industry. In order to encourage investment in the fish industry, Government must have a clear cut policy for aquaculture in general and fish culture in particular. The capital invested in fish farming must be subsidised by low interest rates, outright grants or by providing basic site needs like roads, water supply, electricity etc. Fish culture should be viewed as a means of developing a country's natural resources. The concept of integrated commercial aquaculture may be the main theme of future aquaculture development for becoming a contributing factor in fish production.

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POST-HARVEST TECHNOLOGY AND UTILIZATION*

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INTRODUCTION

POST HARVEST Technology denotes the various handling methods, treatments and operational techniques applied on harvested crop and animal and aquatic products for the purpose of preservation and improvement of quality for marketing. The significance of post harvest technology is that it has the potential to meet the food requirement of growing population by eliminating available losses, developing more nutritive food items from low grade raw commodity, proper processing and fortification and economic utilisation of wastes and by-products. It is needless to say that adequate food production in agriculture or aquaculture and utilisation through processing and distribution must be as a rule nutrition oriented programme, if proper and adequate food intake is to reach all mankind.

Until recently men could afford to be gatherers (by capture) of fish and other marine/aquatic food materials. The conditions have so altered that now they are forced to cultivate the waters also to meet the ever growing demand for this proteinaceous food item. Much has been done and said about the post harvest technology of capture fisheries both in India and abroad. However, since the topic of this symposium is aquculture, I shall confine my observations to the technology of cultured fishes only and that too as it pertains to Indian conditions. Whereas in the capture fisheries the fishes are harvested from sea, rivers, brackish and inland waters as the case may be, from unknown stocks as regard age, sex, maturity etc. under the most difficult conditions, in the culture fisheries, it should be possible to select the species rear them to the required size and maturity and harvest them as required. In this respect, the aquaculture bears close analogy to agri-horticulture, poultry, piggery and animal husbandry where the food grains, fruits and vegetables, birds and animals can be harvested and processed or utilised as and when required at the appropriate or optimum stages of growth.

HANDLING, PRESERVATION AND TRANSPORTATION

The invitation to this Symposium on Coastal Aquaculture is a great honour to me and I am particularly pleased to be here and thankful to the organisers for including my small contribution in the form of this Keynote address. I hope that as a result of this Symposium there will be concerted efforts in enhancing the efficiency of both production and post harvest technology so that more people are able to utilise the product in improving their nutritional status and bettering the country's economy.

As pointed out earlier, the greatest advantage in culture fisheries is that harvesting can be regulated on the basis of demand from the market. The most easily perishable of human food materials, fish is more relished by consumers in the fresh condition than in any

* Keynote address delivered at the Symposium.

processed/preserved form. According to the available statistics, two-thirds of the entire 2.3 million tonnes of fish caught in the country in a year go for consumption in the fresh condition. This records a marked improvement over the figure of 42.7% two decades back and still less in the pre-independence period. This has been made possible by several of the developmental activities launched by the country after attaining political independence. Among these may be mentioned the installation of several ice plants throughout the coast-line as well as at inland production centres, laying of approach roads to as many fishing villages as possible, pressing in the services of quick means of sea, road and rail transport like trucks (insulated as well as un-insulated) carrier launches, refrigerated rail wagons (on selected routes) etc. and applying results of modern technological research.

An All India Co-ordinated Research Project on Transportation of Fresh Fish operated by the Indian Council of Agricultural Research for about one decade has worked out hygienic methods for handling, packaging and transportation of fresh fish including fresh water fishes and cultured brackishwater fishes. Freshly harvested cultured *Chanos chanos* could be transported in an excellent condition by ordinary rail wagons from Kakinada to Howrah packed in plywood boxes insulated with expanded polystyrene slabs. The fish were in live condition when brought to the laboratory for packing and transportation. This method can be applied to other cultured fishes since we are sure of the quality of the fish at the time of despatch. Consumer preference has however to be given prime importance while deciding upon the mode of preparation for packing. Filleting of larger fishes is usually resorted to in other countries before transportation owing to several advantages like exclusion of sources of contamination like intestines and gills, reducing the bulk by removal of other unwanted portions like bones and head and consequent savings in freight charges, because weight for weight, more of edible material could be transported at lesser cost of packaging in such cases. But as far as Calcutta, the largest market for fresh fish in India is concerned, whole (round) fish is the first choice, filleting drastically slashing the consumer acceptance.

Of course, quite a lot of extension work is yet to be carried out for popularising the improved containers and methods of packing with the trade. Even the slightest change from the traditional methods meets with resistance from the fish traders in our country, probably because of the slightly higher monitary investment involved.

FREEZING

Fish freezing industry is well established in the country as far as export commodities like shrimp, lobster tails, froglegs and cuttle fish are concerned. Aquaculture of some varieties of shrimp like *Penaeus indicus* and *P. monoden* has succeeded to varying degrees in the country. Harvest from such sources definitely constitutes the best raw material for the industry, since the processers know the complete history of the raw material source. Every stage of the handling and processing activities in such cases can be programmed. Efforts at aquaculture of frogs are also going on in several places, though commercial success cannot yet be claimed. In case this materialises, the problem of salmonella contamination which has been a serious hazard in this commodity at times, could be tackled in a better way. Best quality products can be turned out by exercising strict control on quality at every stage of processing starting from harvesting.

Cultivated fishes like Chanos, Mullet, Etroplus, Tilapia etc. also lend themselves well to icing and freezing preservation as shown by studies undertaken at our laboratories with the added advantage that the raw material quality at the time of processing/preservation is assured. These fishes exhibit better and longer keeping qualities in both iced and frozen preservation over those procured from unknown sources. A peculiar phenomenon observed in our freezing industry is that more than one half of its installed capacity is lying idle due to short supply of the much sought after export commodity *viz*. shrimp. Recent efforts at freezing and export of cuttle-fish and some other fishes have not been able to make any substantial headway in gainfully utilising the idle capacity. It is at this context that the cultured fishes assume importance. Whatever excess is harvested over and above what is absorbed by the fresh fish market can be preserved in excellent condition by freezing for pretty long periods, so that equitable distribution area-wise and season-wise can be assured, besides earning better returns for those engaged in aquaculture of such fishes.

Some other items of aqaculture which can claim near commercial success are clams, mussels, oysters and eels. Shucked meats of these shell fishes/molluscs lend themselves well for freezing in glazed blocks. Eels can be frozen in round chunks or fillets either individually or in blocks of required size. A host of fresh water fishes like catla, rohu, mrigal etc. which are being cultured in ponds and reservoirs applying the technique of induced breeding already developed could also be well preserved by freezing.

CANNING

Fish canning industry also flourished in our country from the late fifties, of course, only with respect to prawns which had a lucrative export market. The peak export of canned prawns was in the year 1973, a quantity of 2200 tonnes worth Rs. 5.24 crores. The industry declined thereafter due to several reasons with the result that 90% of the installed capacity is now lying idle. Many of the cultured fishes mentioned above lend themselves well to canning. This has been proved in the case of chanos, mullets, eels and etroplus and shell fishes like clams, mussels and oysters. It may not be difficult to extend this technique to other cultured fishes also, so that at least a part of the idle capacity can be gainfully utilised.

CURING AND DEHYDRATION

This method of preservation has not been widely applied to fresh and brackishwater fishes in our country. But recently some of the cultured items like clam and mussel meat, eel etc. have been successfully salted and dried with and without subjecting them to smoking. Being the cheapest method of preservation of fish, this is bound to be popular with the masses living below the poverty line where sufficient quantities of such cultured fishes are made available.

PICKLING

Methods have already been worked out for pickling clam and mussel meat and commercial production of the same commenced at more than one centre in Kerala as a result of the Lab-to-Land programme of the Central Institute of Fisheries Technology on the occasion of the Golden Jubilee of the ICAR in 1979.

WASTE UTILISATION

This problem arises only in the case of canning and fillet freezing of cultured fishes and in prawn freezing where the offal and shell and head wastes are thrown out. Methods have already been worked out for economic utilisation of such materials, like conversion into fish meal for poultry/cattle feed and manure, hydrolysed products for human consumption, edible protein paste and chitosan from prawn shell waste with respect to marine fishes. The very same methods can well be applied for cultured fishes also.

CONSTRAINTS

It has been mentioned at the beginning, the post harvest technology of cultured fishes offers definite advantage over that of capture fisheries in so far as harvesting can be regulated according to the demands of the market. If fish farmers whose role is reduced to producer only is to be made producer-cum-processor it may be necessary to evolve low capacity agriculture based rural industries which are both technically superior and economically viable. Of course, by designing suitable combination of inputs, and culture practices appropriate to each species of fish or combination of species in a location-specific system, it should be possible to offer assured price support to the fish farmer. It is here that the utilisation aspect has its place in the higher category of priorities. Which are the indigenous processing industries which could draw the raw material from aquaculture and which when established and managed wisely would stimulate regional development and provide employment opportunities ? These are required to be planned and implemented only after making a thorough study of all the relevant factors involved. How far such fish processing units established in rural sector could abide by the code of hygienic practices already laid down so that the bacteriological wholesomeness of finished product is ever assured without resorting to compulsory inspection at all stages. The problem requires all the more serious consideration when the raw material for processing is to be drawn from fish cultivated in treated or untreated sewage effluents. Regarding conventional products like dry cured, smoked and pickled products to some extent, without much monetary investment but with little care it is possible to prepare in bulk products with reasonable shelf life. The same is not true when one employs sophisticated technology like freezing and canning where the entire establishments are to be streamlined to the essential requirements of food processing units.

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SEAWEED CULTURE IN INDIA*

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SINCE 3000 B.C. seaweeds have been used by man as food, animal feed, fertilizer, medicines and in chemical industry. More recently they have been used experimentally as a source of fuel and in the recovery of nutrients in recycling aquaculture systems. However, Phycocolloids *viz.* agar-agar carrageenan and algin form the basis of their major industrial utilisation.

All over the world seaweeds have been collected until recently from natural resources. Only in Japan the seaweed planting has been practised for two centuries. In the developing countries there is now a boom in seaweed aquaculture for domestic consumption or for export. And there is a high demand for the phycocolloid-yielding species on the world market. Two famous examples of aquaculture are of *Porphyra* in Japan and of *Laminaria* in China. Since 1973 *Eucheuma* farming has been practised in Philippines and Micronesia. *Gracilaria* farming was developed for its use as food for the milk fish in Philippines and in Taiwan. Literature on seaweed acquaculture has been extensively covered by Cheng, (1969) Bardach *et al.* (1972), Doty (1973), Mathieson (1973), Shang (1976) and Michanek (1979). clearly the present trend is in favour of cultivation to meet the industrial demand for seaweed carbohydrates.

Successful farming methods have been devised to achieve optimal long term growth and mass production coupled with high operational efficiency. The common features of the seaweeds chosen for aquaculture are large size, good harvestibility, good growth, resistance to disease and good content of organic matter. A line of studies is rapidly developing in relation to the demands of their nutrients, temperature, water movement, light, day length, etc., in life-cycle, diseases and grazing. Accepting several seaweeds to cover all the specifications, systematic breeding and selection programmes are being tried to improve the desired properties. California Ocean kelp farming projects of billion dollar magnitude are planned to find a new and renewable source of energy before the natural gas resources are exhausted. In contrast, the Canadian Maritime green house cultivation of Irish Moss is planned to be of benefit to the ordinary fisherman.

In India harvesting of the economic seaweeds from the natural resources has been practised for one and half decades now to meet the demands of industry. While the brown algal reserves seem to meet the present requirements of the algin industry, a dearth for the red algae has long been felt. Realizing the need, aquaculture projects for the agarophytes were initiated. Krishnamurthy (1965) gave an account of the principles and problems associated with seaweed cultivation. So far, *Gracilaria* farming techniques suitable for the coastal waters around Mandapam in the Ramnad District of Tamil Nadu have been developed, rather simultaneoulsy by the Central Salt and Marine Chemicals Research Institute, Bhavnagar and by the Central Marine Fisheries

* Keynote address delivered at the Symposium.

Research Institute, Cochin. Successful *Gracilaria* farming has emerged out of the pilot experiments. Crops were raised using fragments as 'seed' material in the constant-level plantings. In the method developed by the CSMCRI the propagation was practised by the long-line rope method. 20,000 m rope is planted over one hectare and yields 100 tons wet seaweed in 3-4 harvests in a year (Krishnamurthy *et al.*, 1972 ; Raju and Thomas, 1971). The process was released to the interested parties. However *Gracilaria edulis* farming has not yet been commercialized on our coasts, inspite of its economic feasibility. The CMFRI farming method employs nets as the substrata (Umamaheswara Rao, 1974). The pilot farm technology recently evolved by Chennubhotla and Co-workers (1979) has been released to fishermen under the ICAR *Lab to Land Programme*, and is being practised in the coastal waters at Marakayarpatnam, Vedalai and Seniappa Darga near Mandapam. 185 nets each of (5 × 2) 10 m area came under *Gracilaria edulis* farming. A net profit of Rs. 30 accrues to the fishermen from each net, based on the product agar-agar which he produces by a simple cottage-industry method. The venture is hoped to be continued and expanded from the subsidies sought to be available from the Tamil Nadu State Government through IRDP and DPAP schemes.

The efficiency of both the *Gracilaria* farming techniques cannot be contrasted at the moment. However, it would appear that the long-line rope technique is the one suitable for large-scale farms, because greater crop yield will result for the substrate employed in Unit area, since no advantage is gained by employing a net in place of a rope. However, the future possibilities of improving the *Gracilaria* farming efficiency by R & D methods cannot be under estimated.

In contrast, the farming of *Gelidiella acerosa* is still in the experimental stage. Its phenology, growth, propagation and regeneration in the Mandapam region are well understood. The experimental cultivation has been in operation since 1973, soon after the basic technique was worked out by us (the CSMCRI Scientists), as a sponsored project of M/s. Cellulose Products of India Ltd. Ahmedabad/Madurai. At first it was developed into a pilot farm 0.5 ha area at Krusadai during 1973-76, and the technical details on different aspects, *viz.* selection of seed material, time of planting, nature of the substrata, duration of growth, growth rates and the time and number of harvests, have emerged establishing the basic technology for pilot-farms. Here again the vegetative fragments were planted as seed material to raise the crop by vegetative propagation. This is the only possible method as the reproductive life-cycle is not present in the naturally propagating material. The seaweed was found to grow better in the bottom cultures rather than the constant-level plantings, and in open-shore environment (Subbaramaiah *et al.*, 1975 ; Patel, N.B. *et al.*, 1978). Since 1977, the pilot farm has been practised at Ervadi. So far 6 harvests at six-monthly intervals have been taken. The crop yield obtained in the pilot farm is of the order of 0.10 kg/m^2 (dry) in a harvest taken during 1978 (Patel, J.B. *et al.*, 1979), and by the endof 1979 greater yield 0.12 kg/m^2 (dry) was produced. These are atleast three times more than the biomass density to which it now grows in the natural beds at Ervadi. Very dense stands of *Gelidiella acerosa* 1.2 kg/m^2 dry are known to occur in the coasts of Kavaratti island (Union Territory of Lakshadweep). Future programme includes raising better strains by *selection*, and growth hormore treatment of the fragments for raising the crop yield. Therefore, the proposed increase in crop yield to a level of 0.48 kg/m^2 (dry) in order to make the technology economically feasible will be well within the optimal limits of natural growth.

Besides these two seaweeds, aquaculture methods for *Sargassum* and *Padina* for algin, *Hypnea* for carrageenan and *Enteromorpha* for pharmaceuticals are being developed by the CSMCRI in its field stations.

Introduction of certain economic seaweeds, particularly *Eucheuma* from Philippines and a suitable *Macrocystis* from the American waters of the Central Pacific on the Indian shores has also been suggested. There is also scope for the farming of *Phorphyra* of indigenous origin in the costal waters. It is hoped that with the realization of the potentialities for seaweed aquaculture, these projects get the desired boost.

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ABSTRACTS OF PAPERS RECEIVED FOR THE SYMPOSIUM

PROSPECTS FOR MARICULTURE IN THE EAST COAST OF INDIA

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The paper gives a detailed description of the numerous backwater areas and swamps along the east coast of India from Chilka Lake in the north to the Point Calimere in the south. Only Chilka Lake and Pulicat Lake are being utilised properly at present where fishing of some magnitude exists. Seeds of penaeid prawns are available in abundance in the Chilka Lake which could be utilised for large scale prawn farms in and around this area. similarly areas in the estuarine regions of Krishna delta, backwater extending from Bapatla to Ongole, backwaters near Marakanam Backwaters at Killai and areas around Vedaranyam and Point Calimere are rich in prawn resources and prawn culture farms could be located in these areas. Suitable areas for the culture of oysters, window-pane oysters, crabs and fishes in this region are indicated. Fish production could be increased two or three fold if all the areas of the backwaters are put to use properly. It will go a long way in augmenting the income of our fishermen and bring in vast improvements in their economic conditions.

SUITABILITY OF BRACKISHWATER AREA OF RIVER COOUM AT CHEPAUK, MADRAS FOR AQUACULTURE

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The present paper deals with the survival rate and adaptability of cultivable mullets and mussles to polluted waters ; elucidates the toxicity of River Cooum Estuary, its suitability for aquaculture and explores the possibilities of utilising the sewage wastes for fishery resource.

To find out the survival rate and adaptability of mullets of the species *Mugil cephalus* Linnaeus, *Liza dussumieri* (Valenciennes) and *Liza macrolepis* (Smith), a wooden floating fish pen of the size 4 × 3 × 1.5 m made of country wooden planks, covered on all the sides with nylon net (2 mm mesh size) leaving the top side open for the release of fry and fingerlings, was designed and commissioned at a distance of about 500 metres from the mouth of the River Cooum (near Marina Boat Club). For culturing the common Green Mussel *Perna viridis* Linnaeus a raft (1.5 × 1.5 m) made of bamboo poles with coir ropes tied at four corners of the raft was used.

Altogether five sets of culture experiments on mullet fry and fingerlings of the size 35-125 mm (wt. 2 gm-20 gm) were conducted during January-May 1979 in different periods of tidal amplitude. The survival rate of the mullet fingerlings in the first 24 hr period was high (75%) when the fingerlings were released during high tide period which might be due to proper mixing of the oxygen rich sea water with river water. The survival rate gradually decreased when the mullet fingerlings were released at the time of low tide when there was complete depletion of dissolved oxygen due to the sewage mixed inland river water.

A total number of 800 mussel spats in sets of 200 each were transplanted and allowed to attach themselves to coir ropes hung from the corners of the raft. All the 800 spats were alive for 20 days and their survival rate was high (90%). Thereafter, 50% of the experimental animals died. It is inferred that the mortality was probably due to closure of the mouth resulting in a total reduction in the dissolved oxygen.

An attempt was made to relate the survival rate of the experimental animals with the hydrological conditions of the water at the time of experimentation. In the light of the results obtained, the suitability of the River Cooum for further aquacultural practices is discussed.

ECOLOGICAL DISTRIBUTION OF SOME EDIBLE PORTUNID CRABS OF THE PULICAT LAKE

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The Pulicat Lake is an ideal brackishwater body for studying the ecological distribution of some of our large edible crabs namely *Scylla tranquebarica* (Fabricius), *S. serrata* (Forsskal) and *Portunus pelagicus* (Linnaeus). Relative abundance of these crabs in relation to certain ecological parameters such as salinity, dissolved oxygen, nature of the bottom, depth, turbidity, temperature, direction of wind, tidal current of the lake as well as light was studied with a view to obtain full insight into the optimum environmental conditions required for better management of the culture of these crabs in impound waters. Although factors like depth, turbidity, direction of wind, tidal flow, nature of the bottom and to a certain extent the variable salinity of this lake exert some influence, yet optimum light is believed to be the major factor in the distribution of the two species of *Scylla* in the commercial crab grounds of the Pulicat Lake.

STUDIES ON A BLOOM OF FLAGELLATE *HORNELLIA MARINA* IN THE COASTAL WATERS OF CALICUT

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The bloom of the flagellate *Hornellia marina* often occurs along the Calicut Coast from September to January causing mortality of fishes and prawns in the inshore waters, estuaries and fish farms. The results of studies on such a bloom occurred during 9 days in September, 1977 in the surf region of this coast are presented in the paper.

Periodical observations were made on dissolved oxygen, salinity and temperature of the

inshore waters and on the population of the organism at the time of occurrence of the bloom. Dissolved oxygen of the sea water of the affected area fluctuated from 0.3 ml/l to 5.3 ml/l The salinity and temperature ranged from 14.6‰ to 35·6‰ and 25° C to 31° C respectively. The maximum population of the flagellate was 3400 number/cc, relatively high concentration being observed during the day time when the oxygen content of the water was high. It was also observed that the organism increased in number during the high temperature period.

MACROBENTHOS OF NETHRAVATI-GURUPUR ESTUARY, MANGALORE

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The fluctuations in the distribution of the important animal communities living at the bottom of Nethravati-Gurupur Estuary (12° 50' N 74°50' E), Mangalore are discussed in the present communication. The variations in the qualitative and quantitative composition of the benthic communities were followed for a period of 13 months covering an area of 7.3 km². The major communities forming the benthic population belong to the groups of bivalves, polychastes, crustaceans and fishes.

Bivalves dominated in the collections from stations situated at the head of the estuary. Of the two, the Gurupur stretch contributed to the bulk where these molluscs were present throughout the period. Of the eleven species recorded, *Meretrix casta* dominated the collections throughout. *Braehiodontes variabilis* formed the major component at some stations. *Katelysia opima* and *Donax* spp. added to the bulk of the sample along with *M. casta* at some stations. The peak abundance for *Brachiodontes* spp., *Katelysia opima* and *Donax* sp. was in April and May. While *Brachiodontes* were generally abundant at stations having silt and clay as major fractions at the bottom. *Meretrix* sp., *Donax* sp. and *Katelysia* sp. were collected from stations having predominantly sand with silt.

Polychaetes were represented by 4 genera. As a group, polychaetes inhabited the entire stretch of the estuary and were present throughout. Generally a close relation between the quality of the polychaetes and the type of the sediment at the stations was indicated. *Sabellaria* sp. dominated in the collections in stations having fine sand with mud at the bottom and were abundant during April and May, whereas, *Diopatra* sp. and *Flabellaria* sp. were present in regions having sediments with a greater amount of mud. March to May appeared to be the period when they were present in greater numbers.

The contribution of other benthic animal communities appearing in a discontinuous manner in small quantities, was of a low magnitude. Echinoderms were present in the collections at stations nearer to the mouth and at coastal stations of the estuary during January to April.

DISTRIBUTION OF MEROPLANKTON IN NETHRAVATI-GURUPUR ESTUARY, MANAGALORE

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The distribution of meroplanktonic larvae in a tropical estuary is presented in this paper. The important larval groups that go to the constitution of the meroplankton belong to the major benthic groups such as polychaetes, cirripedes, decapods, gastropods and bivalves. The variations in the distribution of salinity in the estuary and the breeding periodicity of the benthic adults control the quality and quantity of the meroplanktonic larvae of this region. At the head of the estuary, gastropod and bivalve larvae were abundant during the post-monsoon and early pre-monsoon periods, while polychaete larvae registered maximum number in the estuary as a whole during the pre-monsoon months. Cirripede nauplii were in peak abundance during November and April.

Caridian larvae appeared throughout the estuary. During the peak monsoon and early post-monsoon they were present only along the upper stretches of the estuary. Considerable quantities of protozoea and mysid stages appeared in the plankton during pre-monsoon months at stations situated near the middle and mouth of the estuary. Crab larvae were generally found in large numbers in the early post-monsoon months.

HYDROGRAPHY OF NETHRAVATI-GURUPUR ESTUARY, MANGALORE

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The hydrography of the Nethravati-Gurupur Estuary (12°50′N 74°50′ E) covering a water spread area of 7 km^2 has been worked out for a period of 15 months. Monsoon is the most important natural phenomenon which controls the variations in the hydrographical characteristics. A clear cut stratification was noticed during the early post-monsoon months. The surface waters in the deeper part of the estuarine stretch has neutral pH, highly oxygenated (7.49 ml/l) and low salinity from June to August. The nutrients were recorded in high quantities throughout the estuary during June to November and the nutrient budget seems to be mainly controlled by the freshwater run off during monsoon and early post-monsoon periods.

BRACKISHWATER FISH FARM OF ANDHRA PRADESH FISHERIES CORPORATION LTD., KAKINADA, INDIA

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Andhra Pradesh Fisheries Corporation Ltd., a State Government undertaking has taken up a centrally sponsored pilot scheme for the development of Brackishwater Fisheries at Kakinada, on the east coast of India at Lat 16° 56′ 42″ N Long. 82° 15′ 45″E in about 76 hectare plot. The first phase of construction of a pond area of 30 hectare has been completed. The area in and around the farm has been surveyed and it is found that the stocking material of fish and prawn is available in sufficient numbers in nature. During the construction, several problems have been encountered. Certain unexpected ecological conditions have been faced. The oozed water in the tanks have shown salinities over 130‰. Some of the ponds have shown different temperatures at the bottom and the top layers in a water column of 1 metre, the difference being surprisingly over 10°C. In certain parts of the project site where the sand content is more it was getting drifted in the high breeze. The observations during the construction phase of the farm have been detailed in brief and steps to remedy these problems have been discussed in the paper.

UTILISATION OF WASTE HEAT IN AQUACULTURE

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Considerable amounts of waste, heat are available in effluents from power plants. In recent years attention is being given, especially in Japan and U.S.A., to the possibilities of using this waste heat for aquaculture. The present report deals with some aspects of water heat utilisation, including the limitations inherent in the present state of the technology.

MATURATION AND SPAWNING OF *SAURIDA TUMBIL* (BLOCH) IN PORTO NOVO WATERS

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The present paper deals with the maturation and spawning of an important demersal fish, *Saurida tumbil* (Bloch) collected from Porto Novo during the period of October, 1977 to September, 1978. Eight stages of maturity are identified microscopically and four stages macroscopically. Spawning season and spawning frequencies are determined based on ova diameter measurements and distribution of maturity stages in different months. These are further supported by gonadosomatic, and hepatosomatic indices and occurrence of eggs, larvae and juveniles. Spawning time was determined based upon the collection of eggs and larvae from plankton samples during different time intervals. Males are found to attain maturity earlier than females. In addition, size at first maturity, sex ratio and fecundity have been discussed in detail.

STUDIES ON SOME ASPECTS OF BIOLOGY AND SEEDING OF THE CLAM *MERETRIX CASTA* (CHEMNTITZ) IN BHIMUNIPATNAM BACKWATERS

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The age and growth of *Meretrix casta* (Chemnitz) determined by length frequency method indicated that 0-year and 1 year old groups constituted the population in the Bhimunipatnam Backwaters. The growth of clams was found to be faster in cages kept on the substratum than those suspended above. The relationships between length and height and length and thinckness in clams ranging in size from 5 to 45 mm were found to be linear. The breeding period of *M. casta* was relatively short, lasting from April to June.

Seeding in virgin areas with young specimens of *M. casta* measuring 5-20 mm showed very poor survival. Hydrological data from Bhimunipatnam were presented and attempts were made to correlate these data with the seeaing and survival of clams.

SEA URCHIN RESOURCES OF WALTAIR COAST

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A potential resource of the little known black sea urchin, *Stomopneustes variolaris* is reported along the Waltair Coast. The survey along the 30 km coast-line revealed the presence of sea urchin, the resource of which was estimated to be over 1224 tonnes distributed at an average rate of 8.5 numbers per square metre. The concentration of sea urchins was more in the crevices of rocks and sheltered areas than on the open rocky bottom. As the roe of sea urchin is a cherished delicacy and has a good export potential, the possibilities and prospects of culture of this species in suitable areas along the Indian Coast are discussed.

UTILISATION OF BOTTOM SLUSH FROM SLIGHTLY POLLUTED ESTUARINE AREAS FOR PLANKTON PRODUCTION

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The effect of the addition of small doses of estuarine slush to pond soil for increasing the production of fish food organisms in brackish-water medium is reported. Experiments were conducted in glass jars using brackishwater (Salinity 15 ± 1 ppt) with slightly alkaline pond soil low in phosphorus, nitrogen and organic matter as substratum. Air dried and powdered estuarine sediment obtained mainly from city sewage was added uniformly to these experi-

mental jars @ 50% of pond soil. Super phosphate and trace elements such as molybdenum, boron and zinc were also applied separately to study their added effect in improving the nutrient status. Molybdenum gave the best plankton growth followed by boron, super phosphate and zinc. Better plankton production was obtained with estuarine slush alone when compared with pond soil. The changes in the nutrient status of water and soil were also studied.

EFFECT OF SOME ORGANIC SUBSTANCES ON THE LARGE SCALE PRODUCTION OF BRACKISHWATER FISH FOOD ORGANISMS

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The paper presents the results of the effect of various cheaply available organic substances in the mass culture of selected brackishwater micro-organisms under yard conditions with a view to meeting the demand for feeding young prawns and fishes. Filtered brackishwater enriched with a basal dose of yeast was used as culture medium. Extracts of fresh cowdung, ground nut oil cake and vegetable leaves, powdered blue-green and green algae and yeast were applied separately or in combination of two or more items. Of these, leaf extract alone and also in combination with other organic substances gave the maximum yield followed by ground nut oil cake, yeast and blue-green algal powder.

LABORATORY CULTURE OF *ALONA TARAPOREVALAE* SHIRGUR AND NAIK USING ORGANIC AND INORGANIC FERTILIZERS

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Alona taraporvalae Shirgur and Naik was cultured in the laboratory using two organic fertilizers, comprising of groundnut oil cake and urea in combination with the inorganic fertilizer, Sodium hydrogen phosphate-anhydrous in six different combinations and quantities to determine the best combination for massculture of the species. Initial standardization of groundnut oil cake and urea solutions indicated that 1 ml of each of these holding 11-12 mg of solutes was adequate for 1 litre of cultural media at 48 hours interval wheras, 1 ml of the phosphatic stock solution with 2 mg of solute was administered per equal quantity of the cultural media when required. These experiments show that maximum productivity of *Alona taraporevalae* was obtained in the combination of groundnut oil cake and the phosphate.

Observations on fertilizer activity in the cultural media showed that groundnut oil cake steadily decomposed in these media and con sequently generated the biomass of one kind of bacterium. *Pseudomonas acriginosa*. Under the optimum cultural conditions the peak of *Alona* populations was simultaneously accompanied by the peaks of the other organisms. The other organisms comprised of mainly the protozoans with ciliates predominating than mastigophores. However, it was observed that in the usually filter feeding activity by the *Alona* those other organisms do not contribute to their feeding significantly because under purely bacterial conditions, the proliferation of *Alona* proceeds normally as observed. The *Alona* appeared to be healthy and active whenever the cultural media developed uniform suspension of thin walled unicellular green algae. The lagal cells were seen in the gut of the *Alona*. Thus, in the cultural media, combination of *pseudomonas acriginosa* and suitable suspended algal cells constituted ideal food for maximum productivity of *Alona*, yielding 6-7 lakhs of organisms per m^3 of culture medium.

OBSERVATIONS ON THE ACCLIMATISATION OF *DIAPTOMANS* SP. AND *MOINA* SP. TO SALINE WATER

S. R. GHOSH AND G. V. KOWTAL

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In connection with culture of grey mullet *Mugil cephalus* Linnaeus it was observed that the fry of this fish readily accepted freshwater plankton comprising *Diaptomans* sp. (Copepod·) and *Moina* sp. (Cladocera). These plankters added to saline water did not survive. In this context an experiment was set up to study the salinity tolerance of these plankters and the possibility of their acclimatisation in saline water.

It was observed that in the salinity range from trace to 4.50‰, these plankters survived without any mortality for a period of more than 72 hours. At 5.50 to 6.00‰ salinity range no mortality occurred till 2 hours after which only a few survived by the end of 6 hours. In salinity range of 8.00 to 9.00‰ they started dying from the first hour itself and within two hours all died. And at salinity of above 9.25‰ they died instantly.

As it was noticed that these plankters can thrive in the salinity 4.50‰ another experiment was conducted to examine the possibility of enhancing the tolerance by acclimatisation of these freshwater plankters gradually from 4.47‰ to the higher concentration of salinity. It was observed that by this way salinity tolerance of the plankters could be increased to the level of 5.26‰ till 96 hours without and mortality. This also could be increased to 5.50‰ with 25% mortality till 120 hours any 5.80‰ with 50‰ mortality till 144 hours and with 75% mortality till 168 hours.

THE USE OF PLATE SEPARATORS IN CONTINUOUS MASS CULTURE OF *ARTEMIA SALINA*

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The efficiency of a plate separator for isolating the eggs and nauplii from the continuous mass culture tanks of *Artemia salina* under laboratory conditions has been described. In addition to separating the cysts and nauplii from the culture tanks, the apparatus is also useful for recirculating the water and to remove the faeces and other sediments. A plate separator of 56 × 40 × 58 cm size with 2.5 cm air-lift pipe can displace 3 to 4 litres of water per minute. The use of different types of plate separators has also been discussed.

STUDIES ON PHYTOPLANKTON IN POLLUTED WATERS

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Seasonal and spatial distribution of phytoplankton in the pollution-hit areas of the Periyar river tributary near the industrial belt of Alwaye have been studied. The station near FACT is noted for the total absence or poor concentration of phytoplankton; the high NH_3-N (20 to 500 μg at l^{-1}) recorded at the station appears to inhibit the rate of photosynthesis. The remaining stations on either side show comparatively less NH_3-N concentrations and support more phytoplankton production.

EXPERIENCES ON ECOLOGICAL MONITORING OF A REGION IN THE ARABIAN SEA RECEIVING INDUSTRIAL EFFLUENTS

N. R. Menon, T. R. C. Gupta, V. Hariharan, R. J. Katti, N. A. Reddy, A. E. Eknath and H. P. C. Shetty
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Monitoring an ecosystem in the sea, to find out the effects of pollution, has got certain amount of applicability. Such studies are particularly important when those ecosystems are put to maricultural use. The present paper deals with the results gathered from an exhaustive study of the ecology of a waterspread area of 20 km^2 in a region of the Arabian Sea, during the period April, 1975 to May, 1979 before and after it received effluents from a fertilizer complex. Methodology adopted for an effective environmental monitoring is described. If followed for a certain span of time, the results are likely to give explanation to the possible changes in the area from an ecological standpoint.

The results so far gathered show that subtle to major fluctuations occur in the distribution of nutrients containing 'N'. The N : P ratio was affected during certain periods. There was an increase in the standing crop of phytoplankton ($>60\mu$) in the area subsequent to effluent discharge. It is possible that the addition of urea through the effluents is one of the reasons for this increase. Further, the increase which is confined to near shore stations shows that the amount of urea received is not sufficient enough to fertilize the whole area that was monitored. A positive P/Z correlation was obtained for the coastal stations and negative ones for deeper stations. This probably denotes changes in the structure of the whole community. However, no concrete evidence to conclude that there are drastic changes in the composition of zooplankton at the higher trophic levels was obtained. Notwithstanding this, a reversal in P/Z relationship is of significance. It seems probable that the discharge of effluents containing urea is exerting a fertilizing effect of a localised nature.

EFFECT OF POLLUTION ON FISH AND WASTEWATER AQUACULTURE

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The first manifestation of water pollution generally results in fish mortality which may be acute or chronic. The contamination of inland and coastal waters with a variety of industrial effluents and domestic wastewater renders water unfit for fish life and several mass mortalities have occurred. Developmental activi.ies lead to increased demand for water. Industrial activity invariably results in the production of solid, liquid and gaseous wastes. Liquid effluents impair the quality of water which is detrimental to fish and other aquatic life. The wastes may affect the fish directly or indirectly by destroying the fish pond (plankton). Fish being a source of valuable protein should be protected from industrial and domestic pollution.

The wastes could be classified into: (i) oxygen depleting types containing large amount of decomposing organic matter, (ii) inert organic or inorganic wastes causing turbidity problems, (iii) wastes at high temperature causing thermal pollution, (iv) wastes affecting the taste of fish flesh, (v) wastes containing toxic ingredients and (vi) radio active wastes.

Wastewater treatment in oxidation pond using algal ladden effluents for pisciculture have been found to be appropriate as their performance is good and fish production supplements protein deficiency. Aquaculture experiments with stabilization pond effluents using. *Cyprinus carpio* and air breathers have been conducted at Nagpur and using *C. carpio* and polyculture have been concluded at the College of Engineering, Guindy, Madras. Fish growth studied in the above pond systems, with other relevant environmental factors showed that the yield of 7 tonnes per hectare per year has been computed for *Cyprinus carpio* and in the polyculture system a harvest of 11.5 tonnes per hectare per year has been achieved. These aquaculture experiments show a significant method by which domestie wastes can be effectively treated, along with the nutrient recovery through fish production. The additional revenue generted meets part of the operation and maintenance cost of the treatment systems and also control pollution. The various factors of industrial and other pollutions in relation to fish life and experimental observations on aquaculture in waste waters have been presented in this paper.

STUDIES ON DYNAMICS OF BACTERIAL DECOMPOSITION AND NUTRIENT REGENERATION IN THE INSHORE WATERS OFF COCHIN WITH A NOTE ON THE TOLERANCE LIMITS FOR FISH AND SHELLFISH CULTURE

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A survey of bacterial population in sediments with deposits of decaying *Salvinia* and overlying water was made from the inshore waters off Cochin from January to June 1978. The total bacterial population varied from 22.24 × 10^6/ml to 188.26 × 10^6/ml. The sediment population varied from 86.40 × 10^6/gm to 306.26 × 10^6/gm. The sediment samples particularly clayey samples always harboured maximum population. Totally 45 strains were isolated from 6 stations, 21 of them were in stations nearer to Cochin harbour compared to 24 strains isolated from stations south of Cochin. 20 tests were made on each strain in order to understand their physiological properties. A nutritional grouping study of the predominant bacteria indicated a significant increase in incidence of bacteria requiring amino acids (only casamino acids vit. free) and a decrease in incidence of bacteria requiring mud extract in the fishing grounds receiving decayed *Salvinia* remains. A decline in the water/sediment ratio of proteolytic, amnylolytic and lipolytic bacterial population was noticeable in the stations south of Cochin near Chellanam area, where there is a possibility of greater accumulation of organic deposits. This indicates that the marine environment formed by microbes of organically rich clayey sediments in the fishing area is not similar to the marine environment formed by sandy sediments where the weed accumulation is less. The observed qualitative abundance ofthe 6 enzyme-using bacteria is also statistically compared with the other hydrographic parameters. The tolerance limits for water quality for shellfish and commercial fish culture are also discussed.

DIVERSIFICATION OF FISHERY PRODUCTS

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The fact that almost 70-80% of our marine fish landings from mechanised fishing consist of fish which fetch an uneconomically low price and only about 15-20% of the catch is made up of quality fish/prawn has already highlighted the need for diversification of the fishery products based on economically low grade fish in order to render the fishing operations economically viable. While the emphasis on shrimp culture would naturally be on the raising of large sized prawns such as *Penaeus monodon* and *P. indicus* or quality fishes, there are several other species of smaller prawns/fishes which could also be reared and produced

in large quantities. The very large quantity of small sized non-penaeid prawns landed particularly in the Maharashtra area needs serious attention *immediately* from this aspect. Modern technology has shown the way for utilising even such small sized prawns, whose only demerit is that they are too small to be handled and marketed profitably in the conventional way. The present paper discusses these and allied problems of diversification in the marketing of fisheries products, based on shrimp and fish, produced by aquaculture practices.

BACTERIAL FLORA IN THE ALIMENTARY CANAL OF *RASTRELLIGER KANAGURTA* (CUVIER)

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A study on the aerobic bacterial flora of the alimentary canal of the Indian mackerel, *Rastrelliger kanagurta* (Cuvier) showed that, of the three regions investigated namely oesophagus, stomach and intestine, the last two harboured maximum bacterial populations. The relationship between bacterial population and feeding index was significant. The morphological, biochemical and physiological characters of the representative isolates were studied. *Bacillus*, *Corynebacterium* and *Vibrio* were encountered commonly. The isolates were nutritionally classified into seven groups based on their requirements for amino acids and other growth factors. Variations in bacterial populations in relation to the type and quantity of ingested food, to the various nutritional requirements to the composition of the food are discussed. Importance of the present type of study in fish spoilage, fish preservation and in fish nutrition is indicated.

MIXED CULTURE FERMENTATION AS A PREDOMINANT BIOLOGICAL PHENOMENON IN THE PRODUCTION OF FERMENTED FISH PRODUCTS

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It is well-known that microorganisms are involved in the production of fermented fish products, and the microbial profile is specific to individual products. In the production of fish sauce where *koji* is mixed with fish meat, fermentation is by yeasts, mould and bacteria. Among the Lactobacilli, *Lactobacillus plantarum* and *L. pentoaceticus* are the organisms commonly involved. The basic substances such as ammonia, cadaverine, piperidine and acids like acetic, propionic, butyric, valeric and lactic, and alcohols and esters of the respective acids, formed by fermentation reaction are found to be the flavour imparting compounds in the fermented fish products. The lactic acid and ethyl alcohol formed in the fermentation of fermented fish along with the residual salt prevent spoilage of these speciality products of the orient.

SOCIO-ECONOMIC CONDITIONS OF THE CHANK FISHERMEN COMMUNITY IN TUTICORIN, SOUTH INDIA

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A sample survey to study the socio-economic conditions of the chank fishermen community in Turicorin was conducted during March-May, 1979 to ascertain the socio-economic conditions prevailing and the effect of developmental schemes on the socio-economic conditions at a later date. A total of 304 houses were studied for their demographic and economic conditions and the results presented.

The percentage distribution of males and females is 51.9 and 48.1 respectively. Children constituted 43.5% and adults 56.5%. All the adult females and 95.7% of males are illiterate. Percentage of school attending male and female children are 57.4 and 47.3 respectively. Nearly 41.4% of the households have income in the range of Rs. 101-200 per month by gainful activity. In about 83.4% cases, the source of the loan is private money lenders for the household purposes and fishery enterprises. 85% have 'Kuchcha' houses and 15% semi-pucca houses. Information on the sanitation and drinking water supply of the households was also collected and discussed.

SOCIO-ECONOMIC STATUS OF FISHERFOLK OF PORTO NOVO, TAMIL NADU

K. MUNIYANDI AND N. JAYABALAN

Central Marine Fisheries Research Institute, Cochin-682 031, *India*

Supported by the marine, estuarine, backwater and mangrove fin-fish and shellfish fishery resources, Porto-Novo along the Coramandel Coast is an active fishing centre. The types of crafts and gears employed for the exploitation of the fishery resource and the approximate cost and total investment, in the fishing industry of this region were discussed. Per capita income of an active fisherman was calculated for the period of from March, 1978 to February, 1979. The impact of monsoon on the fishing activity of the area and the effect of cyclone of November, 1977 on the socio-economic life of fishermen were discussed. Suggestions for further development of the fishing industry through capture and culture fisheries and for the improvement of the socio-economic life of the fishermen of the area are presented.

SOCIO-ECONOMIC STANDARDS OF FISHERMEN OF MARAKAYARPATNAM AND VEDALAI VILLAGES IN TAMIL NADU AND THE ROLE OF COASTAL AQUACULTURE IN RAISING THEIR STANDARDS

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Central Marine Fisheries Research Institute, Cochin-682 031, *India*

The villages of Marakayarpatnam and Vedalai are located on the south-east coast of India in the Ramanathapuram District of Tamil Nadu. The main livelihood of the fishermen in these villages is fishing (chank fishery, gillnet, shore-seine and cast net operations) and collection of economically important seaweeds from the neighbouring islands. There are no cultivable lands in Marakayarpatnam but in Vedali coconuts, plantains, flowering plants and ragi are cultivated in 395 acres. The population of the former is nearly 500 and of the latter around 2000. At Marakayarpatnam and Vedalai potable water is drawn from unprotected well situated about 1 km away from the villages.

Most of the people reside in Kuchcha houses and live in poverty. The per capita income is around Rs. 300-400 per month. Most of them do not have education beyond primary level. For medical attendance these people have to go to Panchayat Union Dispensary at Mandapam which is 10 km away and the special treatment is available only at Ramanathapuram which is 35 km away. Only a few houses are electrified in these villages.

There are potentialities for carrying out mariculture of prawns, turtles lobsters, milkfish, mullets and seaweeds in land-based ponds and in the shallow coastal waters by suitable methods. By culture of these economically important fishes and seaweeds the economic standards of fishermen could be considerably improved. While suitable technologies for the culture of these organisms are being developed, non-availability of finance to the fishermen in view of their poor economic status has been found to be one of the major constraints in the development of mariculture in this region. These aspects are discussed in the paper.

TRANSFER OF TECHNOLOGY OF SEAWEED CULTURE

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Central Marine Fisheries Research Institute, Cochin-682 018, *India*

Experiments on cultivation of economically important seaweeds have been carried out during the past few years at the Central Marine Fisheries Research Institute and suitable techniques of culture of agarophytes (*Gelidiella acerosa* and *Gracilaria edulis*) and alginophytes (species of *Sargassum* and *Turbinaria*) have been developed. The culture technology evolved comprises of introduction of small fragments of the seaweed into the twists of the coir rope fabricated in the form of nets and tied to fixed poles in the inshore waters and monitoring their growth. An yield of 3 kg/m²/ was obtained for *G. edulis* and *G. acerosa* in 60 and 80 days respectively from an initial seed material of 1 kg. To transfer the technology of seaweed culture to farmers and entrepreneurs need-based training programmes have been instituted. The details of the training courses, their content and utility are discussed in the paper.

Summary of the Proceedings of the Symposium on Coastal Aquaculture

SYMPOSIUM ON COASTAL AQUACULTURE

SUMMARY OF THE PROCEEDINGS

The Inaugural function of the Symposium on Coastal Aquaculture was held on 12th January 1980 at the Kerala Fine Arts Society Hall at Ernakulam. Dr. E. G. Silas, President of the Marine Biological Association of India presided over the function. His Excellency Shri K. C. Abraham, Governor of Andhra Pradesh delivered the inaugural address and declared the Symposium open. He expressed in his inaugural speech the importance of Aquaculture which is the golden key which can open the coffers of the oceans and rivers for man to prosper, and he congratulated the Marine Biological Association of India for organising the Symposium. Dr. E. G. Silas welcomed the distinguished guests and delegates, and delivered his Presidential address in which he explained the birth, growth and the present status of the Marine Biological Association of India. He also stressed the need and the importance of the present symposium to augment fish production to supplement the protein food much needed by the country. Shri K. Balachandran, Worshipful Mayor of Cochin and the Chairman of the Reception Committee welcomed the delegates to the city and felicitated the function. Shri Philipose Thomas, District Collector, Ernakulam also gave a felicitation address on the occasion. Dr. R. Raghu Prasad, Vice-President of the Marine Biological Association of India and Assistant Director General (Fisheries), Indian Council of Agricultural Research, New Delhi gave a talk on 'Prospects of Coastal Aquaculture' at the inaugural function. Dr. P. V. Ramachandran Nair, Secretary of the Association proposed a Vote of thanks. The function came to an end with the National Anthem.

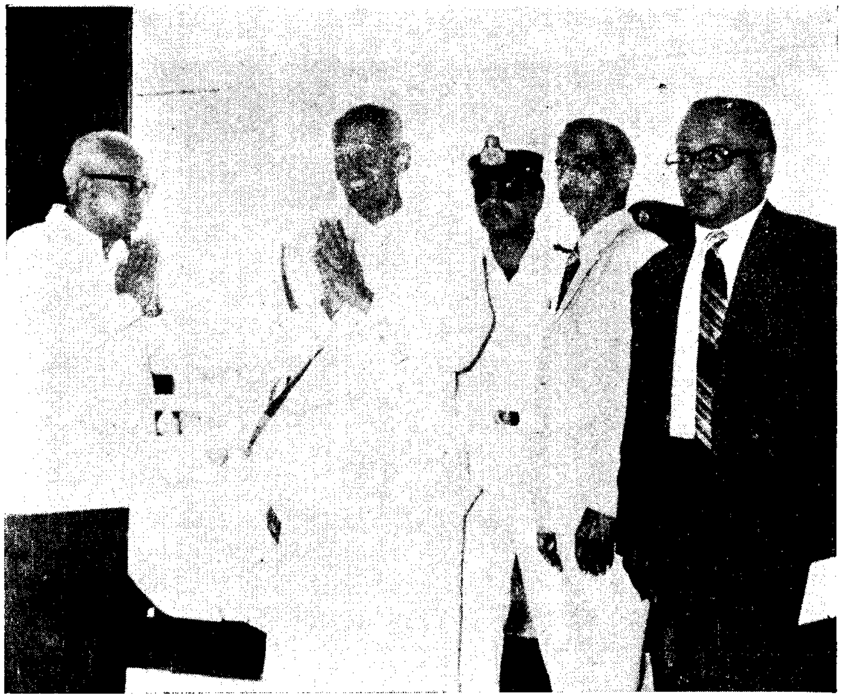
On the occasion of the Symposium, the Marine Biological Association also arranged an exhibition on Coastal Aquaculture at the Campus of the Department of Marine Sciences, University of Cochin which was declared open by His Excellency Shri K. C. Abraham, Governor of Andhra Pradesh. The exhibition depicted the current coastal aquaculture activities, the different technologies developed and the extension activities for accelerating the growth in this sector in the country. The exhibition which was open to the public, drew a good crowd.

The Scientific Sessions began in the afternoon of 12th January 1986 at the Banquet Hall of the International Hotel, M. G. Road, Ernakulam. Some of the sessions were taken concurrently on following dates at the Banquet Hall and the Meeting Hall of the International Hotel. All the twelve Technical Sessions were attended by the delegates. The programme list of the different Technical Sessions, the Chairman and Rappoteurs for each Session are listed in the accompanying Technical Programme. The key-note address given at different Technical Sessions by the experts are also indicated in the programme. In the afternoon of 18th January 1980, the delegates reviewed the various aspects on Coastal Aquaculture discussed in the Technical Sessions and proposed and formulated the nine Recommendations which are given here.

Special lectures and film shows were also given by Dr. Patrick Sorgeloos, Artemia Reference Centre, State University, Plateaustraat 22, B 9000 Ghent, Belgium on 'Recent developments in *Artemia* culture'; Mr. Heine, Tilapia International Foundation, 27 Avenue E. Cambier, 1030 Bruxelles, Belgique on 'Tilapia Culture'; Mr. R. Madhavan Nayar, Cochin Company, Cochin on 'Strategies of Coastal Aquaculture in India'; and Dr. A. Prakash, Department of Environment, EPS, Ottawa, Canada on 'Aquaculture in Canada'.

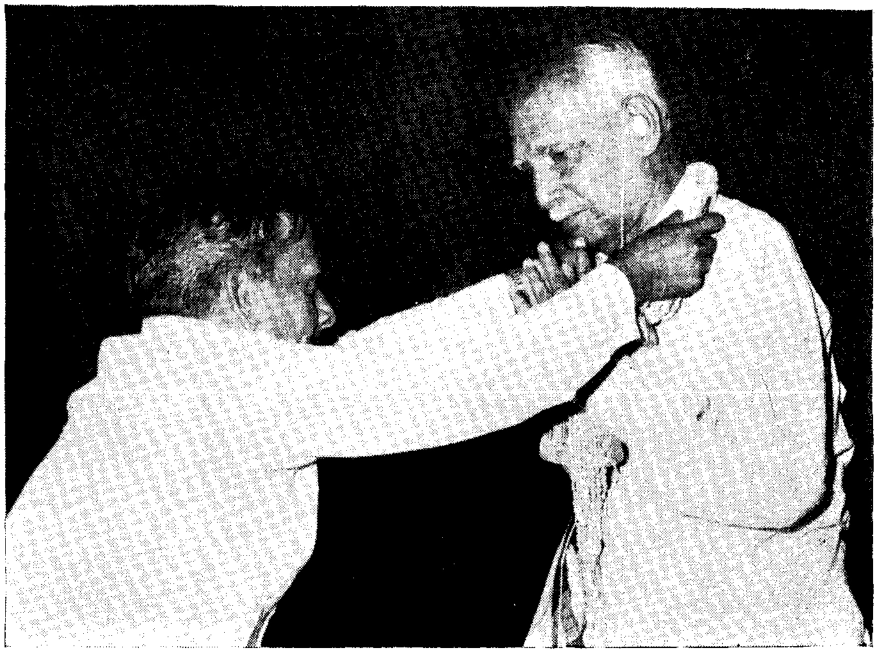
A field trip was arranged for the delegates to Narakkal Prawn Hatchery Laboratory of the Central Marine Fisheries Research Institute and to the Lab-to-Land Centre at Valappu for witnessing the integrated paddy and prawn culture activities at the village level. The Association also published a booklet 'Fisheries Research and Development Institutes in and around Cochin' for distribution to the participants along with a booklet containing 'Abstracts' of the papers presented at the Symposium and a Programme Booklet.

Cultural programmes arranged by the Association on Kathakali, Bharathanatyam, Kuchipudi and Kaikottikali were well appreciated by all participants.



A warm reception to His Excellency Shri. K. C. Abraham.

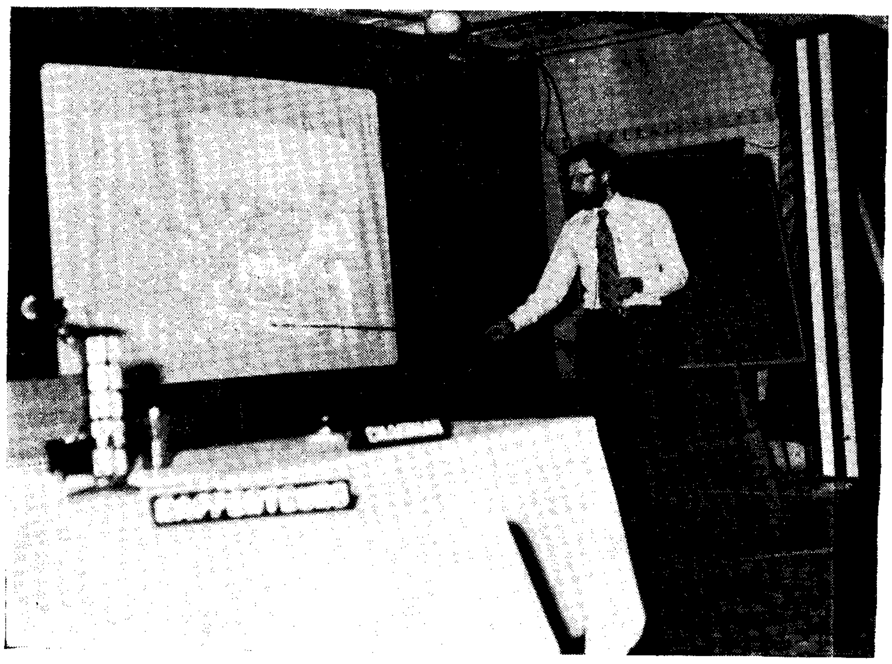
Dr. E. G. Silas, President of the Marine Biological Association of India delivering his Presidential Address.



His Excellency Shri K. C. Abraham is garlanded by Dr. P. V. Rao, Co-Convener of the Symposium.

His Excellency Shri K. C. Abraham is delivering his inaugural address.

The Distinguished Guests are (from left to right) Dr. C. T. Samuel, Department of Industrial Fisheries University of Cochin ; Shri. Philipose Thomas, District Collector, Ernakulam ; Dr. E. G. Silas, President, Marine Biological Association of India and General Convener of the Symposium on Coastal Aquaculture ; His Excellency Shri. K. C. Abraham, Governor of Andhra Pradesh ; Shri. K. Balachandran, Worshipful Mayor of Cochin ; Dr. R. Raghu Prasad, Vice-President of Marine Biological Association of India and Assistant Director General (Fisheries) I.C.A.R. ; Dr. S. Jones, Founder President of Marine Biological Association of India ; Dr. C. V. Kurian, Department of Marine Sciences, University of Cochin ; Shri. R. C. Choudhury, Chairman, M.P.E.D.A. and Shri. G. K. Kuriyan, Director, C.I.F.T.



Dr. Patrick Sorgeloos is giving his special lecture on ' Recent developments in *Artimta* Culture '.

A deep discussion at a technical session. Dr. K. N. Sankolli at the mike.

Chairman Mr. G. K. Kuriyan expresses his views at the technical session 'Post-harvest Technology and Utilization'. Shri R. Balan and Shri T. K. Govindan are the Rapporteurs.

INAUGURAL ADDRESS OF HIS EXCELLENCY SHRI K. C. ABRAHAM, GOVERNOR OF ANDHRA PRADESH AT THE SYMPOSIUM ON COASTAL AQUACULTURE ORGANISED BY THE MARINE BIOLOGICAL ASSOCIATION OF INDIA AT COCHIN ON 12TH JANUARY 1980

1. I am doubly happy to be here this morning; happy that I am amidst the august company of scientists, technologists, educationists and administrators drawn from the different parts of the country and outside and happy that I am in the midst of most familiar surroundings which are exuding Nature's Wealth. When I utter the words 'Nature's Wealth', I am nostalgically reminded of my intimacy with the sea where 'the wild white horses are at play' on the surface. Beneath this surface, to unfathomable depth, bounteous Nature treasures its wealth, ready to be purveyed to the mankind. It is for man to harness this treasure to the benefit of one and all. It is in this context, pursuit of Aquaculture acquires considerable importance.

2. Inquisitive and interrogative as one is, one is inclined to ask what benefits such an pursuit confer on the society. To find an answer to this thought provoking question, one will have to look not at the sea, but at the land upon which man lives and multiplies. With population multiplying with march of time, the need for food for sustenance increases simultaneously. In an effort to meet this increasing need, larger and larger areas of land are brought under the plough. Incessant research is carried on to increase the productivity of land. This has resulted in the replacement of conventional varieties of seeds by high yielding varieties. Irrigation potential is being exploited to the maximum with a view to converting dry lands into wet lands and creasing agricultural production. These efforts are not without constraints and production also cannot increase limitlessly. Man should therefore, turn to other resources to meet his deamnds. Nature which has endowed man with fertile lands, again comes to his rescue by providing plentiful resources in water in rivers, lakes and oceans. Aquaculture is the Golden Key which can open the coffers of oceans and rivers for man to enjoy and prosper.

3. Man has been exploiting land to the fullest extent resulting in gradual depletion of its ferility. Food produced by land is becoming less and less nutritive. Studies have revealed that food from land is deficient in proteins. Malnutrition is the cause of many dreadful diseases. To a person suffering from such diseases, life is listless and burden some. He will not be able to play his part in the world and contribute his mite to the welfare of the society. Instead, he becomes a pain in the neck of the society. Such a situation should be averted, by gearing human efforts towards securing protein rich food. Nature again offers man a helping hand by making available to him protein rich food in the vast stretches of sea. Aquaculture enables man to have access to this highly nutritive sea food.

4. It is time that attention is bestowed on the study of coastal resources. 'Full many a gem of purest ray serene, the dark unfathomed caves of the ocean bear'. It is reported that some of the world's most abundant fishing grounds yield an annual harvest of 10 billion dollars. May I digress a little from the subject to remark that as the world grows short of fossil fuels attention is being focussed increasingly on the oil and natural gas resources of oceans. Already about 20 per cen of the world's oil comes from off shore wells and this figure is likely to shoot up in the coming decades as the energy squeeze tightens. A recent U.N. study puts the amount of oil in the continental margins at a staggering 2,272 billion barrels. There is also coal and iron, tin, limestone, sulphur, barium ore and diamonds, resources which yield a few hundred million dollars annually on a global basis. What an enormous wealth the sea stores underneath its surface !

5. The question arises whether man has taken full advantage of these hidden resources for his betterment. The answer is in the negative undoubtedly. Restricting statistics to aquaculture it is estimated that out of 440 million hectares of coastal wet land in the world, only 3 to 4 million hectares are presently used for culture purposes. In India there are about 2 million hectares of estuaries an brackishwater areas potentially suited for aquaculture. Of these, only 5,000 hectares in Kerala and 20,000 hectares in West Bengal are utilised for traditional brackishwater fish and prawn culture. Presently, over 60 countries in the world, have focussed their attention on aquaculture producing six million tonnes annually, valued at 2.5 billion dollars which constitute about 8 percent of the total world fish production. Figures justify the observation that in the field of aquaculture utilization is a small percentage of the available resources. Now that it is admitted that man should turn to sea to fill up the gap in production of nutritive food, the question troubling man's mind is how to make maximum use of these resources ? What measures should be taken up to achieve this objective ? There is no better forum than this intellectual gathering to discuss the question threadbare, deliberate upon it and offer concrete and constructive suggestions which can be implemented and the rewards reaped.

6. Notwithstanding the fact that I am remotely competent to comment on this highly technical subject, I take this opportunity to express my, — a layman's — views on the subject. Aquaculture as understood by a non-technical person is farming of animals and plants in aquatic media. It can ge considered as a branch of animal husbandry, if the latter term is used to include both the rearing of domestic aimals and the harvesting and management of wild game. Fish culture is the most important aspect of aquaculture. Fish culture can be broadly divided into the following sectors:

1. Growing fish for consumption.
2. Stocking fish in open waters.
3. Improvement of the habitat.
4. Regulation of fishing for best yield.

Fish for consumption can be grown adopting one of the following methods: (1) Pond culture in temperate climate, (2) Tropical pond culture and (3) Brackishwater pond culture.

7. Rivers offer plenty of scope for pond fish culture. In China, along the YANGTZE River there exist 1,800 shallow flood-plain lakes covering eight million acres which are controlled to varying degrees for fish rearing. An intensive investigation of other major rivers the world over is called for with the object of expanding pond fish culture. A rapidly developing branch of

tropical and warm temperate fish culture is the use of rice fields for growing fish. Most rice fields produce a few wild fish, grown from fry brought in with the irrigation water. By suitable stocking and fertilising, large yields can be obtained from various crops. The potental fish production of the world's rice fields is enormous. Even though this Symposium is only on ' Coastal Aquaculture ' advantage can be taken of the experience of experts to discuss all aspects of aquaculture without confining it to the coastal areas, so that a clear picture on the prospects of aquaculture will emerge, facilitating formulation of cmprehensive schemes.

8. Brackishwater pond culture has immense potentialities in marshy and river delta areas. Most of the fishes used in this technique are of marine origin; they breed in the sea, but the young seek brackish or even fresh water. In southern France, along the upper Adriatic Coast of Italy, in India, Indonesia, the Philippiness and Japan, there is ample scope for conversion of river deltas into such fish rearing establishments. How best this area can be enlarged and the annual catch increased, are issues which can be discussed at length at this Symposium.

9. There is much scope for additional improvements in hatchery techniques. Experiments were conducted with cohoes at Minter Creek in Washington. It was found that native stream reared smolts produced 5 to 15 times as many adult fish as pond-reared smolts of the same stock. Improved diets or other changes should gradually eliminate this differential. It is gathered that transplanted fingerlings do not return to a stream nearly as successfully as fingerlings of the native stock even when the two are similarly reared and similarly treated. The causes and full implications of the phenomenon are not known clearly—have the missing fish gone some where else or have they perished ?

10. Introduction of new species into the existing breed with the intention of improving growth offers ample opportunities for research and development. Success can be measured with reference to the variety and abundance of the native fish farms and an equation established.

11. Changes in lakes and streams and construction of fish passes and screens are some of the methods adopted in improving the habitat of fish. But to any mind, the most important method is the one pertaining to reduction of mortality from predation. There are numerous kinds of animals which compete with man in consuming useful fish. Quite often predators attack usable fish concentrated in limited areas. For example, sea lions may follow a troller and take salmon of the line; gray seals can very skilfully rob pond nets, an abundance of dog-fish makes trawling difficult, kingfishers and herons gorge on trouts from unprotected ponds and so on. Methods should be so chosen that they do away with the predators without killing fish. Sometimes, it appears, treatment of water with a poison in the correct concentration kills the young predators without harming fish. Different kinds of predators may reuire different methods of treatment under different conditions. A thorough study is necessary for arriving at methods for different situations. This Symposium can serve as an eye opener for tackling this problem exhaustively by offering valuable suggestions which could be experimented with.

12. Yet another important aspect of fish culture is the framing of regulations to obtain best yields. The objectives of the regulations should be two-fold : (1) to make best use of a stock of fish already in existence and (2) to provide a maximum supply of future recruits. An indepth study of the problems pertaining to exploitation and yield is necessary in order to frame appropriate regulations. These problems no doubt are numerous. For instance, during the cycle, the individual fish may become large enough to be useful to a man. However, if the year class is still

increasing in bulk it may be desirable to wait and begin harvesting when a larger total weight is available. But, harvesting should not be delayed too long or the year class will have passed into the declining phase. The question that arises for consideration is when should the fish be harvested ? What are the factors relevant to best exploitation of the existing stock ? Likewise in order to have adequate recruits year after year, the spawning stock must not be allowed to become too small. The question is how small is too small ? Can a spawning stock be too large ? In view of little understood variability in survival of fish eggs what should be done about in maintaining a spawning stock ? What absolute number of spawners in each stock will give the best average yield ? It is for all of you who are assembled here to ponder over these and allied questions, exchange ideas and offer pragmatic suggestions for maximum yield.

13. While accent should be placed on aquaculture for increasing the production of sea foods, we should take care that the existing stock is not depleted by indiscriminate fishing and irrational fishing methods. Sea is no doubt bounteous, but not without limits. As indiscriminate sinking of wells will deplete ground water resources, so is the case with the resources of the sea. Between 1951 and 1971 the global fish catch quadrupled. Yet many stocks have been depleted by over-fishing. Scientists report that there have been drastic decline in the catches of certain species of herring, cod, sardines and salmon. It is for the experts who are present here to highlight the hazards of over-fishing and enlighten those who have taken fishing as an occupation, on these aspects of fishing. They may do well to prepare lucid, concise handouts couched in non-technical terms for the benefit of one and all.

14. While on this subject, one should take note of the problem of pollution caused by rapid industrialisation. The Baltic, Mediterranean and Caspian Seas already are so polluted that marine life is severaly threatened. Many scientists fear that if such onslaughts continue unabated, the ocean's regenerative capacity will be eventually destroyed. Sea is being used as a global garbage dump for a variety of human and industrial wastes with scant regard for the effect on the ocean's ecological system. Eagerness to exploit natural resources should be equipoised with the need to maintain the ecosystem. The intellectual gathering here will be rendering a yeoman service to the maintenance of ecological balance in the seas by bringing to surface these hard truths and impressing upon the society the need to save the ocean from disaster.

15. Harnessig of coastal resources in the best possible manner will kindle economic activity and catalyse industrial growth. New ventures based on sea foods will germinate offering ample employment opportunities. Such a situation will go a long way in solving the problem of unemployment. The industrial activities in this new direction will open vistas for trade and commerce.

16. Despite the fact that the deliberations will be at a high level of specialisation, we should not forget that the ultimate aim is to benefit the society as a whole and fisherman — an economically and socially backward person occupying a bottom rung in the economic and social ladder, in particular. Measures formulated and methods suggested should be economical and easy of acceptance by the professional fishermen. The experts assembled here will function as friends, philosophers and guides to them, encourage and advise them and make sure that the path is well laid for betterment of the community. In this manner we should try to achieve the economic and social objectives behind our national policies.

17. I understand that scientific research in aquaculture has commenced only some sixty years ago. The period has been marked by considerable growth of technological advancements in different culture systems. Some of the developed and the developing countries in the world have been significantly benefited by the different systems. Happily in our country there is already a vast reservoir of information on aquaculture arising out of pioneering research undertaken by several organisations. The question before us is how best we can employ the available modern techniques in aquaculture not only to put available knowledge to immediate use in important channels, but also to encourage and nourish further investigations.

18. It is a wonderful thing that scientist, technicians, experts, administrators and planners have come together in this forum. I hope that this get-together will iron out the obstructions to the horizontal flows of information. It is only through occasions such as these the progress in different branches of specialisation and the efforts of administrators can be welded and moulded into a common effort aimed at obtaining basic and lasting benefits for mankind.

I have great pleasure in inaugurating the Symposium and in wishing your deliberations all success.

JAI HIND

PROSPECTS OF COASTAL AQUACULTURE*

I consider it a privilege to participate in this Symposium and to be in the midst of active scientists as well as practical aquaculturists and entrepreneurs. I must thank Dr. Silas, President of the Marine Biological Association of India for giving me this opportunity.

The Marine Biological Association of India was founded in 1958 with a view to fostering marine sciences in this part of the world. Dr. S. Jones former Director of the Central Marine Fisheries Research Institute, who is happily amongst us here, is the founder President. The Association had a humble beginning with a small group of scientists working at Mandapam Camp in a remote corner of India. Within a short time, the Association grew from strength to strength and today, it has an international membership of 900 including individuals and institutions. Almost all the institutions which have an involvement in any discipline of marine science have become regular Members of this Association. The Association has so far organized five Symposia, and the present Symposium is the sixth in the series. All the Symposia organized so far have generated considerable interest among the scientific community and many scientists of international reputation from India and abroad have participated in the Symposia and have made significant contributions. The Proceedings of the Symposia covering various disciplines have reached all parts of the world and they form important reference work in the respective fields. This is no small achievement for an Association started on a small-scale and it has already gained an important place in the marine sciences and fisheries map of the world. This Symposium on Coastal Aquaculture which is inauguarated by His Excellency the Governor of Andhra Pradesh is specially significant in view of the increasing awareness of the fact that coastal aquaculture has immense potentialities for augmenting natural food production.

Coastal aquaculture is an ancient practice of raising sea food and has its origin in Asia. Some of the traditional systems such as oyster culture in Japan and milkfish culture in the Far-East are several centuries old. India, for its part, also has age-old practices of paddy-cum-prawn culture along the margins of the backwaters of Kerala and fish and prawn culture in the bheris in the Sunderbans of West Bengal. However, the efficiency of these systems has remained low and very little scientific management practices are involved. Today the governments of several countries and international bodies are giving a high priority for developing aquaculture.

This Symposium is concerned with coastal aquaculture, that is cultivation of aquatic organisms along the edge of the sea and the contiguous brackishwater regions. Compared to aquaculture in the freshwater areas, developments in coastal aquaulture are more recent. The countries like Japan, U.S.A., France, Italy, Holland, Korea, Philippines and U.K. gave the lead by developing technologies for the culture of species of high unit value. Japan which depends mainly

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* Talk given by Dr. R. Raghu Prasad, Vice-President of the Marine Biological Association of India and Assistant Director General (Fisheries), Indian Council of Agricultural Research, New Delhi at the inaugural function of the Symposium on Coastal Aquaculture.

on the sea for meeting the protein requirements of her people has the greatest interest in coastal aquaculture. In most of these countries highly sophisticated technologies are employed in the production of finfishes such as the yellow-tall, plaice, salmon and catfish, crustaceans such as prawns and crabs, molluscs such as oysters, mussels, pearl oysters and abalones and seaweeds. Attempts are being made to culture even oceanic species of tunas. These are high-cost technologies, but are still profit-yielding becase of the high unit value of the product.

Coastal Aquaculture is the youngest among the programmes of fisheries development in India. It has been estimated that we have about 2 million hectares of brackishwater areas including estuaries, backwaters, mangrove swamps and lagoons, but the traditional system exploits about 30,000 ha of this water area. Our species resource is varied and rich with a number of economically important finfishes, shellfishes and seaweeds suitable for culture. The pressure on capture fisheries in the coastal waters is increasing and some of the traditional grounds are believed to be overfished. The capital cost and running expenditure of the fishing vessels are increasing day by day. Under these circumstanes, the only course of action open for getting additional production is to resort to the farming of the sea. Coastal aquaculture will have the advantages of increasing production of animal protein, producing high-priced varieties such as prawns for export, creating employment opportunities in the coastal sector and putting large areas of water bodies into productive use.

We have made a good beginning in developing technique for the culture of a variety of organisms during the last few years. For prawn culture, methods for intensive farming of selected species in seasonal and perennial fields have been evolved. This has given production rates of 1 to 1.5 tonnes/ha/year. Indigenous techniques for pearl culture have been developed and the rate of production of cultured pearls is over 60%. Multiple implantation has increased the rate by about three times. Open-sea mussel farming gives a production of over 500 tonnes/ha/5 months in a water column of 8 metres. Oyster culture yields about 150 tonnes/ha/year. Techniques for running water eel culture have been developed. Culture of milkfish, mullets, pearlspot, sandwhiting and 'bhekti' has given moderate yields with simple techniques of farming. Seaweed culture in the coastal areas has become practicable.

While considerable progress has been made in developing these techniques, we have a long way to go to be able to sustain and advance the interests of the coastal aquaculture industry. We have the technical knowledge, but we must develop our scientific capabilities to deal with situations arising out of the application of this knowledge in large-scale operations. I would also like to suggest to the scientists that the technologies they develop should be relevant not only to the water and species, but to the socio-economic situations of the country. High-input, high-energy and capital intensive technologies may not be relevant to the Indian conditions. Our technologies should be within the economic means and technical capabilities of the fish culturist and must produce commodities which are within the purchasing power of an average consumer. Synergic use of the ecosystem should be made through integration of crop-livestock-fish productions systems.

Fortunately India has a good scientific base in fisheries in its research institutes. The Central Marine Fisheries Research Institute, the Central Inland Fisheries Research Institute and the Central Institute of Fisheries Education have research, training and extension programmes in aquaculture. The Central Institute of Fisheries Technology is seized of the post-harvest technological problems. The Indian Council of Agricultural Research, under whose aegis these Institutes function, is giving the required support for their programmes. The Council has also initiated a cooperative programme of training scientists in aquaculture with the South East Asian Fisheries Development Centre of Philippines. To improve the quality of research and teaching in this field a UNDP/ICAR Centre of Advanced Studies in Mariculture has been set up at the Central Marine Fisheries Research Institute. This Centre should play a key role in evolving appropriate technologies in coastal aquaculture not only for India, but for the whole of the South-east Asain region.

The need for programmes on transfer of technology of coastal aquaculture has been realised. Horizontal transfer of technology from the Research Institute to the farmers' fields has been taken up in the field of coastal aquaculture. This enabled the scientists directly to come in contact with the field conditions and have a grip on the problems of the fields as well as people who are the clients. The National Demonstration Programmes, Operational Research Projects, Rural Aquaculture Project and the recently introduced Lab-to-Land programmes are efforts to transfer the improved and proven technologies to the fishermen and fish farmers.

The State Governments which are responsible for the development of fisheries have an important role to play in the development of coastal aquaculture industry. They should lay down suitable policies for leasing out land and water areas to the fishermen and fish farmers for practising aquaculture and provide necessary infrastructural facilities. The financing agencies also should come forward to support this nascent industry. A strong extension base should be built up for the vertical and horizontal transfer of technology and for getting the feed-back.

The prospects for coastal aquaculture in India, from the viewpoints of resources, recent technological developments and scientific capabilities and the national support it has, are exceedingly good. The interest is spreading far and wide. This has to be judiciously supported so that a large section of the people of the coastal sector are benefited by this technology.

The shore-land, inter-tidal regions, backwaters, estuaries etc. are complex ecosystems and also are clearly regions of conflicting interests and demands. Fishing or fish-farming, agriculture, waste disposal, construction of harbours, industrial undertakings including petroleum production and recreation are a few of these. Therefore, the objectives should be categorised into long-term conservations and developments and a coordinated planning based on scientific data in imperative. Nearly a decade back, an international symposium on Coastal Lagoons was held in Mexico to highlight the various problems in this dynamic environment and find solutions to the conflicting interests. I am confident that this Symposium will discuss and evaluate the present status of our knowledge in the different aspects of coastal aquaculture and establish new trends of investigations.

SYMPOSIUM ON COASTAL AQUACULTURE
COCHIN, INDIA * 12-18 JANUARY 1980

PROGRAMME

11 January 1980, Friday

Hours

1000—1700 **Registration**

Venue : S. T. Reddiar Building (Opposite to International Hotel), M. G. Road, Cochin-682 011.

12 January 1980, Saturday

0830—1030 **Registration**

Venue : International Hotel, M. G. Road, Cochin-682 011.

1100—1230 **Inauguration of the Symposium**

Venue : Kerala Fine Arts Theatre,
Foreshore Road, Cochin-682 016.

1230—1300 **Visit to Exhibition**

TECHNICAL SESSIONS

Venue : International Hotel

12 January 1980, Saturday

Banquet Hall

1345—1400 Meeting of Chairmen and Rapporteurs

1400—1700 SESSION I : PRESENT STATUS OF COASTAL AQUACULTURE

Chairman	..	Dr. E. C. Silas
Rapporteurs	..	Dr. K. K. Tiwari
		Dr. S. V. Bapat
Keynote Address	..	Dr. E. G. Silas

13 January 1980, Sunday

Banquet Hall

0930—1300 SESSION III : REPRODUCTION AND GENETICS

Chairman	..	Dr. B. I. Sundararaj
Rapporteurs	..	Dr. Kiran M. Desai
		Dr. D. M. Thampy
Keynote Address	..	Dr. R. Nagabhushanam

Meeting Hall

0930—1300 SESSION V : CULTURE TECHNOLOGY, PRODUCTION AND ECONOMICS

SECTION 7 : CULTURE OF LIVE-FOOD ORGANISMS

Chairman	..	Dr. Patrick Sargeloos
Rapporteurs	..	Dr. Susan M. Kamel
		Mr. K. Nagappan Nayar
Keynote Address	..	Dr. David Kahan

1430—1800 **Local visit to places of tourist interest.**

14 January 1980, Monday

Banquet Hall

0930—1300 SESSION IV : SEED PRODUCTION AND TRANSPORTATION

Chairman	..	Dr. R. Raghu Prasad
Rapporteurs	..	Prof. C. V. Kurian
		Mr. K. H. Mohamed
Keynote Address	..	Mr. K. H. Alikunhi

Banquet Hall

1400—1700 SESSION V : CULTURE TECHNOLOGY, PRODUCTION AND ECONOMICS

SECTION 1 : FINFISH CULTURE

Chairman	..	Dr. S. Jones
Rapporteurs	..	Dr. P. J. Sanjeeva Raj
		Mr. G. Venkataraman
Keynote Address	..	Dr. P. S. B. R. James

15 January 1980, Tuesday

Banquet Hall

0930—1300 SESSION V : CULTURE TECHNOLOGY, PRODUCTION AND ECONOMICS

SECTION 2 : CRUSTACEAN CULTURE

Chairman	.. Mr. K. H. Alikunhi
Rapporteurs	.. Dr. K. N. Sankolli
	Dr. A. N. Ghosh
Keynote Address	.. Dr. P. V. Rao

1400—1900 Visit to Prawn Culture Laboratory of the Central Marine Fisheries Research Institute at Narakkal and the Regional Shrimp Hatchery of the Department of Fisheries, Government of Kerala, at Azhikode.

16 January 1980, Wednesday

Banquet Hall

0930—1300 SESSION V : CULTURE TECHNOLOGY, PRODUCTION AND ECONOMICS

SECTION 3 : MOLLUSCAN CULTURE

Chairman	.. Dr. R. Natarajan
Rapporteurs	.. Shri. S. Mahadevan
	Mr. K. A. Narsimham
Keynote Address	.. Dr. K. Alagarswami

Meeting Hall

0930—1300 SESSION V : CULTURE TECHNOLOGY, PRODUCTION AND ECONOMICS

SECTION 4 : SEAWEED CULTURE

5 : CULTURE OF OTHER ORGANISMS

6 : POLYCULTURE AND INTEGRATED FARMING

Chairman	.. Mr. G. N. Mitra
Rapporteurs	.. Dr. M. J. Sebastian
	Dr. M. Umamaheswara Rao
Keynote Address	.. Dr. K. Subbaramaiah — Seaweed Culture
	Mr. K. H. Mohamed — Polyculture and integrated farming.

Banquet Hall

1400—1700 SESSION VI : NUTRITION AND PHYSIOLOGY

Chairman .. Dr. M. N. Kutty
Rapporteurs .. Dr. R. Damodaran
Dr. Joseph P. Royan
Keynote Address .. Dr. M. N. Kutty

Meeting Hall

1400—1700 SESSION VII : FISH AND SHELLFISH DISEASES AND THEIR CONTROL

Chairman .. Dr. K. Ramalingam
Rapporteurs .. Dr. K. C. Jayaraman
Mr. S. Mahadevan
Keynote Address .. Dr. Bryan L. Duncan

1830—2030 **Cultural Programme**

17 January 1980, Thursday

Banquet Hall

0930—1300 SESSION II : CULTURE ECOSYSTEM AND FARM ENGINEERING

Chairman .. Dr. P. N. Ganapati
Rapporteurs .. Shri S. T. Chari
Shri M. H. Dhulkhed
Keynote Address .. Dr. N. Balakrishnan Nair

Meeting Hall

0930—1300 SESSION X : SOCIO-ECONOMIC AND LEGAL ASPECTS OF COASTAL AQUACULTURE

Chairman .. Prof. G. M. Gerhardson
Rapporteurs .. Dr. M. J. George
Mr. U. K. Gopalan
Keynote Address .. Prof. G. M. Gerhardson

Banquet Hall

1400—1530 SESSION VIII : ENVIRONMENTAL MANAGEMENT

Chairman .. Dr. C. V. Kurian
Rapporteur .. Mr. K. C. George
Keynote Address .. Dr. P. V. Ramachandran Nair

Banquet Hall

1545—1700 SESSION IX : POST HARVEST TECHNOLOGY AND UTILISATION

Chairman	..	Mr. G. K. Kuriyan
Rapporteurs	..	Mr. R. Balasubramanian
		Mr. T. K. Govindan
Keynote Address	..	Mr. M. R. Nair

Meeting Hall

1400—1700 SESSION XI : MANPOWER, TRAINING, EXTENSION AND CO-OPERATIVE PROGRAMME

Chairman	..	Dr. M. V. Pylee
Rapporteurs	..	Dr. Royden Nakamura
		Mr. T. Jacob
Keynote Address	..	Dr. C. T. Samuel

18 January 1980, Friday

Banquet Hall

0930—1030 SESSION XII : STRATEGIES FOR COASTAL AQUACULTURE DEVELOPMENT

Chairman	..	Mr. R. C. Choudhury
Rapportures	..	Dr. P. S. B. R. James
		Dr. S. Ramamurthy
Keynote Address	..	Dr. T. Banerjee

Banquet Hall

1045—1300 PLENARY SESSION : RESUME AND RECOMMENDATIONS

Chairman	..	Dr. E. G. Silas
Rapporteurs	..	Dr. P. V. Rao
		Dr. K. Alagarswami
Vote of Thanks	..	Dr. P. V. Rao

SYMPOSIUM ON COASTAL AQUACULTURE

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SYMPOSIUM ON COASTAL AQUACULTURE

Cochin, India, 12-18 January 1980

RECOMMENDATIONS

During the past decade, coastal aquaculture has emerged as a field of considerable significance for augmenting fish production. This realisation and pursuant R & D efforts have led to improvements in traditional culture practices and to the development of appropriate new technologies. As a result, a fund of information is now available on certain aspects of coastal aquaculture.

Beginning of the new decade of ' eighties ' is an opportune time to review the progress made in the ' seventies ', and the Symposium on Coastal Aquaculture, organised by the Marine Biological Association of India from 12-18 January 1980, provided the forum for such deliberations. Under 12 Technical Sessions, themes of costal aquaculture relating to present status, culture systems, constraints, potentials and prospects, and strategies for future development were discussed by participants from about 20 countries and international organisations.

The Symposium discussions have enabled to identify the major gaps and suggest the areas of thrust needed for future action in the form of recommendations presented here. While these recommendations are meant particularly for this region, they are also relevnt to other developing countries that endeavour to increase fish production through coastal aquaculture.

RECOMMENDATIONS

1. NATIONAL POLICY AND PLAN

The Symposium,

Noting that Research and Development support for coastal aquaculture in India came forth only from the Fifth-Five-Year Plan,

Realising the potentials of coastal aquaculture for augmenting fish production, improving rural economy and generating large-scale employment,

Observing that at present there is no clear National policy or plan for the development of coastal aquaculture, *Recommends* that a National Policy and Plan be evolved for the development of the coastal and brackishwater aquaculture, providing strategies for research, land and water use, financial incentive, production and marketing, conservation of resources, environmental management and legislation.

2. COASTAL AQUACULTURE RESEARCH

The Symposium,

Taking note that directed researches on coastal aquaculture started less than a decade ago in India and that the technical feasibility of culture of several organisms has been established during this period,

Recognising that further technological developments for augmenting production through coastal aquaculture would be possible only by creating and sustaining a strong research base,

Recommends that high priority be assigned at the National level for coordinated multidisciplinary researches on coastal aquaculture.

3. RESEARCH MANAGEMENT AND COORDINATION

The Symposium,

Being aware that researches on coastal aquacluture are at present carried out by several National and State agencies,

Realising the importance of coordinating these activities for maximising productive research output,

Recommends that a nodal organisation be made responsible at the national level to indntify major areas needing critical research inputs and to monitor and coordinate the progress for aiding accelerated development of coastal aquaculture.

4. SURVEY OF WATER AND SEED RESOURCES

The Symposium,

Considering that India has immense potentials of water and species resources suitable for coastal aquaculture,

Pointing out that adequate data on sites suitable for establishing large-scale culture operations, seed availability and other inputs are not available,

Urges that a comprehensive survey on sites and seed resources be carried out adopting an uniform methodology evolved for the purpose, and

Recommends that a National Plan be drawn up for the above survey and this be implemented with the assistance of Central and State agencies.

5. SEED PRODUCTION

The Symposium,

Recognising that adequate availability of quality seed of cultivable species for coastal aquaculture is of primary importance,

Taking into account that at present the culture operations depend upon the availability of natural seed which show wide spatial and temporal fluctuations,

Recommends that controlled seed production of all cultivable organisms in hatcheries be taken up on a priority basis to ensure steady supply of seed for stocking, and that viable hatchery technology be developed for different levels of seed production.

6. ECONOMICS OF COASTAL AQUACULTURE

The Symposium,

Considering that reliable data on the economic feasibility of different culture operations are not available,

Realising that wider application of the technologies for commercial aquaculture production would-become possible only when proven economic data are made available to the prospective users of the technology,

Recommends that system-oriented, location-specific pilot projects be taken up by the state and parastatal agencies by availing of technical and financial support to establish and demonstrate economic feasibility of the culture systems.

7. POST-HARVEST TECHNOLOGY AND UTILISATION

The Symposium,

Recognising that large-scale application of coastal aquaculture technologies would result in appreciable increase in production,

Further realising that there is need for developing suitable technologies for preservation, processing and marketing of the produce, some of which may be non-conventional items,

Recommends that appropriate post-harvest technologies for quality products be developed with reference to consumer preferences and demands in the internal and external markets.

8. SOCIO-ECONOMICS AND INTEGRATED RURAL DEVELOPMENT

The Symposium,

Being fully aware that coastal aquaculture would develop as a predomiantly rurl-based industry,

Recognising that it could be one of the means for promoting integrated rural development and uplifting the socio-economic standards of the coastal sector,

Recommends that appropriate low-cost technologies be developed and propagated in the coastal rural sector and that they be appropriately blended with crop-livestock—aquaculture farming system of the villages or with the prevailing artisanal fisheries.

9. EXTENSION AND TRAINING

The Symposium,

Noting that development of costal aquaculture in the country is very recent and that neither adequate extension services nor training facilities exist at the moment for extending the technologies to the fields.

Realising that these are the major bottlenecks in the development of coastal aquaculture in the country,

Recommends that need-based extension servics for coastal aquaculture be established in eaeh of the maritime States and Union Territories with trained staff,

Further recommends that Coastal Aquaculture Training Centres be established at appropriate levels to meet the requirements of extension and opeative personnel.

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COCHIN, INDIA * 12-18 JANUARY 1980

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The 'Symposium on Coastal Aquaculture' was held in January 1980 by the Marine Biological Association of India. The Symposium covered different culture systems in the coastal waters including the environment, farm engineering, harvest and post-harvest technologies, training, extension, management and legal aspects of coastal aquaculture. 322 scientific papers were contributed for the Symposium by the Scientists, Technologists and Specialists from India and abroad. These papers, after screening, have been published in the Proceedings of the Symposium as follows :

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