Proceedings of the Symposium on Coastal Aquaculture

COCHIN, INDIA ★ 12 - 18, January 1980

PART 1

PRAWN CULTURE

THE MARINE BIOLOGICAL ASSOCIATION OF INDIA
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From January 12 to 18, 1980

PART 1 : PRAWN CULTURE

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PREFACE

Farming of fishes and prawns in the coastal waters of India has been in vogue since about 3000 years. Though an old avocation, it apparently remained at a subsistence level, confined to a small extent of the water areas in the States of Kerala and West Bengal.

The potentials of coastal aquaculture and the advantages of converting the vast derelict swamps and low-lying water bodies in the coastal zone into productive fish farms for increasing fish production were recognised only recently. This realisation paved way for a series of investigations and developmental activities in the field during the last decade. Technologies for systematic cultivation of fast growing and economically important species of finfishes, shellfishes and other edible organisms were soon developeed. Emerging thus, the coastal aquaculture is now reckoned as the most promising source of the future for steady supply of protein food for the ever increasing human population.

The first Symposium exclusively on coastal aquaculture was held in 1970 in Bangkok. It was organised by the Food and Agricultural Organisation of the United Nations in conjunction with the 14th Session of the Indo-Pacific Fisheries Council's meeting. In December 1978, the Central Marine Fisheries Research Institute organised a 'Seminar on the role of small-scale fisheries and coastal aquaculture in integrated rural development' at Madras, which recommended, for the accelerated development of the field in view of its importance not only for augmenting fish production, but also in improving the rural economy and providing large-scale employment opportunities.

The present Symposium on 'Coastal Aquaculture' was organised by the Marine Biological Association of India which is devoted to promote the causes of marine sciences in the Indian Ocean region in general and in the Indian region in particular. It was held at Cochin, Kerala, South India from 12th to 18th January, 1980. The main objectives of the Symposium were to promote and develop coastal aquaculture technologies by disseminating the knowledge and experiences gained, and modern technologies developed among the scientists, technicians, extension workers, administrators, planners, farmers and industrialists through a review of its present status ; discussions on the technologies of culture of various organisms ; identification of major inputs required for research, development, farming and extension ; production intensification by integrated crop-livestock-fish farming technologies ; assessment of social, economic and legal aspects and through linkages, co-ordination and communication among the national and international organisations involved in research, development and promotion of coastal aquaculture.

The Symposium was attended by 307 participants from India and 47 participants from 22 foreign countries, including the International, Governmental and non-governmental representatives.

The Symposium was inaugurated on 12th January, 1980 by His Excellency Shri K. C. Abraham, Governor of Andhra Pradesh. Dr. E. G. Silas, President of the Marine Biological Association and General Convener of the Symposium welcomed the participants and the invitees. Dr. R. Raghu Prasad, Vice-President of the Association and the Assistant Director General (Fisheries) I.C.A.R. described briefly the activities of the Association and mentioned about the importance of coastal aquaculture and the technological advances achieved in recent years. The participants were felicitated by the Worshipful Mayor of Cochin Shri K. Balachandran. Shri Philipose Thomas, District Collector of Ernakulam spoke in his delightful and inimitable style, on the role of coastal aquaculture in improving the economy of artisans and landless labourers. The inaugural function was concluded with the vote of thanks by Dr. P. V. Ramachandran Nair, Secretary of the Association.

The technical aspects of the Symposium were organised under 12 main Sessions, 7 sectional Sessions and a Plenary Session. Abstracts of 324 papers contributed by the scientists, technologists and specialists from different countries formed the material for discussion. Each of the main sessions, as well as the sectional sessions was conducted by a Chairman who was assisted by two Rapporteurs. The theme of the Session was introduced by a specialist in the form of a key-note address with a review of the concerned subject matter. This was followed by the presentation of papers by individual scientists and discussions thereon. The Session was concluded by a sum up of the sailent points of deliberations by the Chairman. In the Plenary Session, an overview of the Symposium summing up the reports of Sessional Chairmen was made and the recommendations were discussed and adopted.

Dr. Patrick Sorgeloos of Artemia Reference Centre, State University, Ghent, Belgium ; Dr. Anand Prakash of the Department of Environment, Canada and Mr. R. Madhavan Nayar of M/s. Cochin Company, delivered special lectures on 'Recent developments in *Artemia* culture', 'Bule mussel industry' and 'Strategy for coastal aquaculture development' respectively. An informational film on '*Tilapia* culture' was shown by Mr. Heine of Tilapia International Foundation, Belgium in the evening of 14th January, 1980. Another informational film on 'Mariculture' was specially screened by the Central Marine Fisheries Research Institute for the benefit of the participants.

An Exhibition on Coastal Aquaculture was arranged in the premises of the University of Cochin in conjunction with the Symposium for projecting the recent advances made and the on-going activities in the field. The Central Institute of Fisheries Technology, Cochin ; the Central Institute of Fisheries Education, Bombay ; the Central Marine Fisheries Research Institute, Cochin ; the Marine

Products Export Development Authority, Cochin ; the Integrated Fisheries Project, Cochin ; Department of Fisheries, Government of Kerala ; the Kerala Fisheries Corporation and Messers. Diwan Trades, Bombay, participated in the Exhibition.

A detailed report on the deliberations of the Symposium on various recommendations made, will be published in the last Volume of the Proceedings.

As announced earlier, the Association is publishing the papers and the abstracts presented at the Symposium and those accepted for publication by the Editorial Committee constituted for the purpose, as Proceedings of the Symposium in a series of volumes. The present volume, the first in the series, will deal with prawn culture and related aspects. The subsequent volumes containing the papers presented in other technical sessions will follow soon.

Several persons and organisations have toiled for the successful conduct of the Symposium. I take this opportunity to express my gratitude to the Patrons, Members of the Association, the participants, the Authors of papers, the Sessional Chairmen, Rapporteurs, the Chairmen and Members of different Symposium Committees and all those involved in the organisation of the Symposium for their excellent co-operation and assistance. I sincerely thank the Indian Council of Agricultural Research, New Delhi for a token financial grant of Rs. 7,500 given in connection with the Symposium.

E. G. Silas
General Convener
Symposium on Coastal Aquaculture
and
President
Marine Biological Association of India

Cochin,
25-2-1982.

PROCEEDINGS OF THE

SYMPOSIUM ON COASTAL AQUACULTURE

PART 1 : PRAWN CULTURE

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RESEARCH PROGRESS IN THE CULTURE OF PENAEID PRAWNS ALONG THE COASTS OF INDIAN OCEAN AND INDO-PACIFIC

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Abstract

A wealth of information on different aspects of culture of penaeid prawns is continuously being made available in recent years as a result of active R & D programmes taken up by several organisations. A compilation of these information covering the areas such as breeding, rearing, seed production, nutrition and diseases of important species of penaeid prawns being cultured along the coasts around the Indian Ocean and Indo-Pacific, is presented in this paper. This review would be useful to understand the present status of the culture of these prawns and to formulate future strategies.

Introduction

The region covered in this review comprises of the tropical and sub-tropical belt extending from Long. 30°E to 150°W. Aquaculture, in countries such as Bangladesh, India, Indonesia, Thailand and Philippines located here, has been in vogue since time immemorial. Among the different systems of aquaculture being developed and practised in the region at present, penaeid prawn culture is the most dynamic field receiving the attention of scientists, administrators, planners, industrialists and farmers. This interest is motivated mainly by factors such as sustaining market demands for the commodity, availability of suitable species and water resources and increasing awareness of the importance and the role of the system in improving the economy and generating employment opportunities in the coastal rural areas.

Following the success achieved by Japan in controlled breeding and rearing of *Penaeus* (*Marsupenaeus*) *japonicus*, most of the countries in the region have turned their attention to developing prawn culture on sophisticated lines. Consequently during the last 50 years, considerable progress has been achieved in the field and a wealth of information has been gathered on various aspects of penaeid prawn culture. The present paper attempts a review of the research and technological progress made particularly in the field of raising prawns in the grow-out systems, seed production, induced maturation and broodstock development, prawn nutrition and diseases.

Species Cultivated

About 82 species, belonging to 8 genera of the family Penaeidae, which are either commercially exploited or possess potential economic value occur in the region. Of these, the species of penaeid prawns cultivated in the region belong mainly to the genera *Penaeus* and *Metapenaeus*. The important species and the countries where they are cultivated are given in Table 1. Among these prawns *P.* (*M.*) *japonicus* and *P.* (*Fenneropenaeus*) *chinensis* are sub-tropical species while the others are tropical. While all the species are found to be suitable for culture, the species belonging to *Penaeus* are preferred over those of *Metapenaeus* as they grow to larger size and have greater market demand. Among the species of *Penaeus*, *P.* (*P.*) *monodon*, the tiger prawn, is the most important as candidate species in view of its wider distribution, largest size, faster rate of growth, greater fecundity and relative hardiness.

TABLE 1. *Important species of penaeid prawns cultivated along the coasts of Indian Ocean and Indo-Pacific*

Species		Countries where cultivated
Penaeus (*Fenneropenaeus*) *chinensis* (Osbeck)	..	Korea, China
P. (*Fenneropenaeus*) *indicus* Milne Edwards	..	India, Singapore
P. (*Fenneropenaeus*) *merguiensis* De Man	..	S.E. Asia
P. (*Fenneropenaeus*) *penicillatus* Alcock	..	Taiwan
P. (*Marsupenaeus*) *japonicus* Bate	..	Japan, Korea
P. (*Melicertus*) *latisulcatus* Kishinouye	..	Japan, Australia
P. (*Melicertus*) *marginatus* Randall	..	Taiwan, Hawaii
P. (*Penaeus*) *semisulcatus* De Haan	..	Taiwan, Thailand
P. (*Penaeus*) *monodon* Fabricius	..	Bahrain, Kuwait, S.E. Asia
Metapenaeus dobsoni (Miers)	..	India
M. monoceros (Fabricius)	..	India
M. ensis (De Haan)	..	S.E. Asia
M. bennettae Racek & Dall	..	Australia
M. brevicornis (Milne Edwards)	..	India, Thailand
M. joyneri (Miers)	..	Korea, Japan
M. stebbingi Nobili	..	Bahrain, Kuwait
M. macleayi (Haswell)	..	Australia

allowed to enter the culture fields during high tide and prevented from escaping during low tide by screens kept in the sluice gates. Harvesting is done during new moon and full moon phases with the help of sluice nets or traps. In this simple and inexpensive method there is no control over the quality or quantity of seed stocked ; no efforts are made to control the predators and no supplementary feed is given. Yields varying from 45-1000 kg/ha/year are obtained by this method.

CULTURE PRACTICES

The culture operations prevailing in the grow-out systems in the region could be conveniently grouped under three categories, namely, extensive culture, semi-intensive culture and intensive culture.

Extensive culture : Traditional methods of trapping and growing penaeid prawns along with fishes such as milkfish and mullets in brackishwater ponds and impoundments in the coastal areas is being practised in Bangladesh, India, Indonesia, Malaysia, Philippines, Singapore, Thailand and Vietnam. In this form of culture the prawn seed which abound in the brackishwater creeks and estuaries are

In Thailand the tidal water is not taken in through the sluice gates but lifted into small enclosures along with the prawn seed by dragon wheels which prevent the large predatory fish from entering the ponds. After accumulating sufficient seed prawns in these nursery enclosures the water is treated with tea seed cake or derris root to selectively kill even the small fish which might have entered along with the prawn seed (Cook, 1976). Then the bunds of the nursery enclosures are cut in places to allow the prawns to move into the surrounding large growing ponds.

The recent trends in improving the yield from this type of culture relate mainly to adoption of better pond management principles. These involve careful preparation of the ponds for stocking by eradication of unwanted organisms in the ponds by tea seed cake and mahua oil cake (both containing saponin) or derris root powder (containing rotenone); application of organic and inorganic fertilizers to enhance the fertility of the ponds; and supplemental stocking of the ponds with the seed of fast growing species such as *P. (P.) monodon, P. (F.) indicus* and *P. (F.) merguiensis* collected from the wild to improve the quality of the yield.

Semi-intensive culture : In this method, the culture ponds are selectively stocked with fast growing species of *Penaeus* and are fed with artificial feeds. The water exchange through the sluice gates is only to maintain the water quality in the ponds and not for stocking purposes.

In Japan, Taiwan and Korea, *P. (M.) japonicus, P. (P.) monodon* and *P. (F.) chinensis* respectively are grown in monoculture in earthern ponds. Hatchery reared seeds are stocked in earthern ponds which may have concrete or brick walls, at stocking densities of 15-20 prawns/m^2. The ponds are well aerated either through perforated P.V.C. pipes laid on the bottom of the pond or through paddle wheels and other mechanical agitators. The prawns are also regularly fed with trash fish, clams or pelleted formula feeds. Yields varying from 2000-3000 kg/ha/year are obtained in commercial scale operation by this method. On an experimental basis, however, an yield as high as 4945 kg/ha was obtained in a culture operation extending over a period of 4½ months in Taiwan.

In India, Indonesia, Thailand, Philippines, Australia and Fiji selective stocking of *P. (P.) monodon, P. (F.) merguiensis* and *P. (F.) indicus* is being experimented in earthern ponds without aerating devices at stocking densities of 1-7 prawns/m^2 and encouraging results have been obtained. Yields of 1000-1185 kg/ha/year have been achieved in India and Indonesia. Polyculture of different species of prawns with milkfish and mullets has also been tried in India.

The results of experiments conducted on semi-intensive method of prawn culture in earthern ponds indicate that a stocking strategy with juveniles measuring 40-60 mm in size gives higher survival and production rate than stocking the field with post-larvae (10-15 mm size); short term culture operations of 2½-4 months duration has distinct advantage over the long term culture which often leads to poor survival and growth; prawns kept in growing ponds beyond 4 months are affected in many ways. The accumulation of metabolic wastes and unused food in the pond soil and the rapid growth of larval fishes that enter the pond along with the tidal waters leading to competition for food or predation, result in stunted growth and poor survival of the stocked prawns. Risk from diseases is also higher. Growth of prawns in the ponds is found to be inversely proportional to stocking density particularly when supplementary feeding is not resorted to in the culture operations. Since the market value of prawns is more for larger prawns it is better to stock a lesser number and obtain a greater size at harvest than to stock a larger number of prawns and get a slightly larger yield of small sized prawns which fetch lower price per unit weight. It is also found that without special aerating devices, the stocking density in natural ponds cannot be increased beyond 10 prawns per m^2.

Intensive culture : In Japan, high density culture of *P. (M.) japonicus* was started in large concrete raceways fitted with double bottom, air lift circulation and continuous flow of sea water along with intensive feeding with clams and trash fish. However, the unused food and moults of prawns accumulating at the bottom posed problems and led to the development of 2000 to 13,000 tonnes concrete circular self-cleaning tanks by Shigueno (1975). These tanks are equipped with false bottom, central drain pipe and constant supply of fresh seawater which is sprayed into the tank in such a way that a circular motion is imparted to the water in the tank which drives the debris towards the middle of the tank from where they are evacuated through the central drain. *P.* (*M.*) *japonicus* is stocked in densities upto 125 prawns/m^2 and fed with pelleted formula feeds. Harvests of 2.1 to 2.6 kg/m^2 of tank surface have been achieved after 6 months in this system.

The construction of these specialised tanks and the logistics of providing such a large volume of running seawater and the complete dependence on pelletised feeds make this system highly capital investment and is found to be economical only in Japan where land and labour are costly and the live prawns command an unusually high market price as a luxury food. The high density culturing is also greatly vulnerable to diseases and large scale mortalities due to mechanical failures even for a short duration.

SEED PRODUCTION

One of the basic requirements for proper planning of the culture operations entails availability of quality prawn seed as and when required by the culturists. The distribution pattern and abundance of prawn seed in the coastal lagoons, estuaries and brackishwater areas exhibit wide fluctuation. In fact inadequate supply of prawn seed forms a major constraint in the development of prawn culture in the brackishwater ponds in Indonesia, Philippines, Thailand and India. To overcome this, hatchery propagation of penaeid prawns under controlled conditions has been perfected in Japan, Korea and Taiwan and is being developed in other countries of the region such as Philippines, Indonesia, Australia, Thailand, Hawaii, Tahiti, Malaysia, India, Bahrain and Kuwait.

The larval rearing system which was developed by Fujinaga and his associates in Japan over a period of 30 years has undergone several changes (Fujinaga, 1969). During 1933-1964, the larvae were grown indoors in porcelain tiled tanks and fed with separately grown pure cultures of *Skeletonema costatum* in the protozoea stage and with *Artemia* nauplii in the mysis stage, and finely chopped clam meat in the postlarval stages. In 1964, Kittaka started fry production in large out door concrete tanks of 50-200 tons capacity. The basic principle of this 'Community culture' method is to rear the larvae along with food organisms in the same tank by proper management of nutrient concentration, vigorous aeration and control of light intensity. This system of larval rearing is now adopted in many hatcheries in Japan to produce several hundreds of millions of fry annually. The method although involves relatively less labour and operational cost, is dependent on a ready supply of large volumes of good seawater. Further, when the sun light is poor the diatom bloom may not develop or the diatoms which develop may not be suitable as feed for the larvae, and this often results in poor survival of the larvae. To compensate the poor growth of diatoms finely powdered Soycake (Hirata *et al.*, 1975) or compounded feed is added @ 1.5 g per 10,000 larvae. However, the difficulties encountered in maintaining sustainable diatom blooms and good quality rearing water often hamper the hatchery operation. Hence in recent years (since 1974) there is a revival of interest in the earlier system of growing the larvae and the feed organisms separately under more rigorously controlled conditions. Besides Japan, several countries in the region have developed technologies for mass production of prawn seed (Table 2). While commercial scale hatcheries are opened for only a few species such as *P. (M.) japonicus* and *P. (P.) monodon*, they are still in an experimental stage for several species as seen in the Table 2.

The recent trend in the mass production of penaeid prawn seed in the region is to develop low-cost technologies for adoption at the village level by using smaller containers and substituting the expensive *Artemia* nauplii with other cheaper food organisms such as *Brachionus*, *Moina* and nematodes, for feeding the mysis stage larvae. The experiments using blended

TABLE 2. *Countries in the Indian Ocean and Indo-Pacific region where mass production of penaeid prawn seed is developed*

Country	Species	Production level	Source
Australia	*P. (M.) latisulcatus*	commercial	Pownall (1974)
China (Main land)	*P. (F.) chinensis*	experimental	Ryther (1979)
Hawaii	*P. (M.) marginatus*	experimental	Gopalakrishnan (1977)
India	*P. (P.) monodon*	experimental	
	P. (F.) indicus	experimental	
	P. (F.) merguiensis	experimental	
	P. (P.) semisulcatus	experimental	
	M. dobsoni	experimental	CMFRI
	M. monoceros	experimental	
	M. affinis	experimental	
	Parapenaeopsis stylifera	experimental	
Indonesia	*P. (F.) merguiensis*	experimental	Anon. (1976)
Japan	*P. (M.) japonicus*	commercial	Shigueno (1975)
Korea	*P. (F.) chinensis*	commercial	Kim (1967)
	M. joyneri	experimental	Lee & Lee (1969)
Malaysia	*P. (P.) monodon*	experimental	Anon. (1973)
	M. ensis	experimental	
Philippines	*P. (P.) monodon*	commercial	Platon (1978)
	P. (F.) merguiensis	experimental	
Tahiti	*P. (P.) monodon*	commercial	AQUACOP (1977)
	P. (F.) merguiensis	commercial	
Taiwan	*P. (P.) monodon*	commercial	Liao (1977)
	P. (M.) japonicus	experimental	
	P. (P.) semisulcatus	experimental	
	M. ensis	experimental	Liao and Huang (1973)
	M. joyneri	experimental	
Thailand	*P. (F.) merguiensis*	experimental	Ruangpanit (1971)
	P. (P.) semisulcatus	experimental	Kungvankij *et al.* (1972)
	P. (P.) monodon	experimental	Kungvankij (1976)

wet tissues of *Acetes* and mysids (Hameed Ali, 1980), powdered Soycake (Hirata *et al.*, 1975), fermented kitchen waste (Motoh, 1978) and powdered and micro-encapsulated clam meat (Jones *et al.*, 1979) for feeding the protozoea stages are aimed at replacing the diatoms and algae with more easily prepared feeds. To overcome the difficulties encountered in synchronising the production of diatoms with the development of the larval stages, attempts are being made to concentrate the cultured phytoplankton by centrifuging or flocculation and preserve them either by deep freezing with 10% glycerol as cryoprotectant or simply by sundrying. Experiments in the SEAFDEC, Philippines have proved that the protozoeal stages can be grown on frozen and sundried *Tetraselmis* and *Chaetoceros* (Anon, 1977).

Maturation of Prawns in Captivity

Maturation under controlled conditions

Steady supply of spawners is an essential prerequisite for effective planning of the hatchery operations. In Japan, procuring spawners poses no problems as there is a well organised system for capturing and transporting *P.* (*M.*) *japonicus* alive to the market in ship-board tanks with running seawater. But in all other countries of the region getting spawners for the hatchery is very expensive and uncertain. To overcome this problem intensive studies are being conducted in Japan, Philippines, Indonesia, Tahiti and India to induce prawns to attain full maturity in captivity and to maintain a broodstock. *P.* (*M.*) *japonicus* is reported to have been maintained in captivity for many generations in Japan. In Taiwan, tank reared *P.* (*P.*) *monodon* (Liao, 1977) and *P.* (*F.*) *penicillatus* (Liao, 1973) are reported to have attained maturity and spawned successfully without any special treatment. At the SEAFDEC in Philippines, *P.* (*P.*) *monodon* reared in 120 ton tanks with flow through system and fed with mussel meat have attained maturity and spawned (Primavera *et al.*, 1978). In China, Ryther (1979) reports that *P.* (*F.*) *chinensis* matures routinely in captivity while in Tahiti AQUACOP (1975, 1979) has developed mature captive broodstocks of *P.* (*F.*) *merguiensis*, *P.* (*M.*) *japonicus*, *P.* (*Litopenaeus*) *vannamei*, *P.* (*L.*) *stylirostris* and *M. ensis* in 4 m diameter tanks fed with running seawater through perforated concentric P.V.C. pipes embedded in gravel and coral sand at the bottom and drained through a central drain pipe. The prawns were fed with compounded diets. In Fiji, natural reproduction of *P.* (*F.*) *merguiensis* in 0.2 ha seawater ponds stocked with adults led to the production of 50,000 postlarvae (Lichatowich *et al.*, 1978).

Induced maturation

Eyestalk ablation technique which interferes with the endocrine control of maturation process of the ovary, has been developed to induce prawns to mature in captivity. Induced maturation and subsequent spawning of *P.* (*F.*) *merguiensis* through bilateral eyestalk ablation has been reported by Alikunhi *et al.* (1976) from Indonesia. However, in recent years, unilateral eyestalk ablation has been successfully used to induce *P.* (*P.*) *monodon* to mature in captivity at Tahiti (AQUACOP, 1977) and in Philippines where the experiments were conducted in the net lined bamboo enclosures erected in protected bays (Wear and Santiago, 1976 ; Santiago, 1977; Rodriguez, 1978), in concrete 120 ton indoor tanks with flowthrough system (Primavera *et al.*, 1978) and in circular 12 ton ferrocement tanks constructed on the AQUACOP model (Primavera, 1978 ; Tolosa, 1978); the prawns were fed with fresh or salted flesh of the brown mussel (*Modiolus metacalfi*). In the Prawn Culture Laboratory of the Central Marine Fisheries Reseasch Institute (CMFRI) at Narakkal, *P.* (*F.*) *indicus*, *P.* (*P.*) *monodon*, *M. dobsoni* and *Parapenaeopsis stylifera* have been induced through unilateral eyestalk ablation to mature and remature in 10 ton capacity circular plastic lined tanks, fitted with submerged biological filters operated by air lifts (Muthu and Laxminarayana, 1979). Detailed studies on the neurosecretion and endocrine control of gonadial maturation of penaid prawns are being carried out in Japan and India (Nakamura, 1974; Kulkarni and Nagabhushanam, 1980).

RECENT ADVANCES IN NUTRITIONAL RESEARCH

Food is normally the largest single item in the running expenditure of a prawn farm employing semi-intensive or intensive culture methods. Appropriately enough the major studies on prawn nutrition have been done in Japan on *P.* (*M.*) *japonicus.* These investigations mainly related to the relative merits of the paste and pelletised diet (Kitabayashi *et al.*, 1971) and determination of protein level and aminoacid composition required for optimum growth (Deshimaru and Shigueno, 1972). Contrary to the high protein levels (50-65%) required by *P.* (*M.*) *japonicus*, Colvin (1976) found that in *P.* (*P.*) *monodon* and *P.* (*F.*) *indicus* the optimum dietary protein level was 45.8% and 43% respectively and that any increase in protein levels above these values does not result in proportionate increase in growth rate.

The research results indicated that the aminoacid composition of the best protein source (clam meat and squid meat) for *P.* (*M.*) *japonicus* closely resembled the aminoacid profile of the prawn meat (Deshimaru and Shigueno, 1972). Feeds containing a greater proportion of basic aminoacids like lysine and histidine were better than feeds containing a higher proportion of acidic aminoacids. However, soya bean is said to be good source of protein for penaeids (Kanazawa *et al.*, 1970) although it is low in basic aminoacids and poor in methionine (Deshimaru and Shigueno, 1972). Diets containing pure aminoacids and peptides were found to be inferior to those with intact protein (Deshimaru and Kuroki, 1974; 1975 a, b). A basal diet supplemented with methionine (0.53%) and arginine (0.83%) gave better growth rates; at higher concentrations, however, the growth was inhibited (Kitabayashi *et al.*, 1971 c, d). Free aminoacids also play a role in the palatability of fresh diets; a tactile response is induced in the walking legs of *P.* (*M.*) *japonicus* by glutornic acid (Takei and Ai, 1971).

Recent studies on prawn nutrition have brought to light the importance of lipids (Deshimaru and Kuroki, 1974 a; Guary *et al.*, 1974, 1975) phosphorus, calcium, vitamins (Kitabayashi, 1971 a, d) and sterols in the diets (Teshima and Kanazawa, 1971; Deshimaru and Kuroki, 1974).

It is seen that most of the Japanese works are based on purified diets with an accent on discovering the dietary needs of prawns for various carbohydrates, proteins, aminoacids, fattyacids, sterols, vitamins and minerals and are fundamental to an understanding of prawn nutrition. Compounded pelleted feeds suitable for semi-intensive culture in ponds and intensive high density culture in large concrete tanks are produced by commercial firms in Japan, Taiwan, Korea and Philippines. Although the main ingredients are known, the proportion and method of processing are trade secrets. Squid meal, fish protein concentrates, wheat gluten, tuna testis meal, activated sludge, vitamin mix and mineral mix are some of the ingredients used in Japan in the diets. Shrimp meal as a protein source is said to increase the efficiency of the diets; in fact even 25% to 35% protein levels have given good results with *P.* (*M.*) *japonicus* when shrimp meal is used (Balazs *et al.*, 1973). The high protein level of 50-65% said to be necessary for *P.* (*M.*) *japonicus* by Japanese workers may be due to the fact that casein was generally used as the main protein source by them; casein may not be a suitable protein as its aminoacid composition is different from that of prawn meat. It is likely that by balancing the aminoacid composition of the diet by suitable inclusion of different protein sources such as shrimp meal, Soy bean meal and groundnut cake, an efficient diet with low protein levels around 30% could be formulated. In India inclusion of powdered squilla meal (Ali, 1980) or slaughter house waste (Verghese and Singh, 1979) in compounded diets have yielded good results.

Studies on Diseases of Cultured Penaeid Prawns

Very little work on penaeid prawn diseases has been done in this region. With the introduction of high density culture of *P. (M.) japonicus* in concrete tanks in Japan, mortalities due to bacterial and fungal diseases came to light. Egusa and Ueda (1972) and Fukuyo and Egusa (1974) identified the fungus *Fusarium soloni* as the causative agent for the blackgill disease in pond reared *P. (M.) japonicus*. Severely infected gills collapse and shrink and the prawns die within two weeks. Four different types of pathogenic bacteria identified as *Vibrio* spp. were isolated from the blood and liver of *P. (M.) japonicus* which died in the circular intensive culture tanks (Shigueno, 1975); the basal part of the antenna, oviduct and seminal duct, the hepatic carina and the posterior border and lateral edges of the abdominal shells become blackened or whitened in the diseased individuals. Feeding the prawn with compounded feed mixed with sulfisozole, nifurstyreic acid and chloremphenicol cured the diseased prawns. In high density cultures another infectious gill disease caused by an unidentified bacterium has been discovered; in the initial stages the colour of the gills is dull orange-yellow or light brown and turns black as the disease progresses (Shigueno, 1975). Immersion in 2-3 ppm furazolidone is recommended for treating the affected prawns.

Two types of bacterial diseases decimated the larval population in the hatcheries at Kagoshima (Shigueno, 1975). In one, the mysis and postlarvae lost their appendages and died. In the other known as the 'white turbid liver disease' the midgut gland of the postlarvae become white and they floated inactively on the surface of the water.

At the CMFRI three types of bacterial diseases of pond grown penaeids have been encountered. The most frequent disease is caused by *Vibrio angulllarum* and leads to emaciation and softening of the muscles and thinning of the cuticle. Reddening of the rostrum or telson leading to destruction of these organs and black cuticular lesions are caused by different pathogenic bacteria. In the course of larval rearing mass mortalities due to a bacterial infection was also encountered; the uropods, antennal scales and other appendages become eroded progressively resulting in the death of the larvae.

In the SEAFDEC hatchery in Philippines, mass mortality of larvae due to a fungal disease caused by *Lagenidium* occurs frequently and furnace is being tried to control the larval infections. The AQUACOP team in Tahiti uses the antibiotic Gallymycein and the fungicide 'Treflan' to control infections during larval rearing.

General Remarks

A perusal of the fisheries development programmes of different countries in the region would reveal that the development of penaeid prawn culture is a field to which most of the countries have attached great importance. However, prawn culture is least developed on the east coast of Africa and the Persian Gulf region. A few studies on the nutrition of *P. (F.) indicus* in S. Africa and the experimental rearing of penaeid prawns in Bahrain and Kuwait mark the beginning of interest in penaeid prawn culture in this area.

In India and the S.E. Asian region a great deal of interest is shown in expanding and improving the traditional extensive methods of pond culture. The yield of prawns in commercial culture operations in this system is found varying from 0.3 tonnes to over 2 tonnes/ha/year although achievement of a production rate of 35 tonnes/ha/year in experimental farming is on the records of literature. This indicates that the technology needs further perfection and the production system needs further improvements.

While the development of hatchery system for prawn seed production, formulation of efficient compounded diets, monitoring of the stocked prawns in the field, control of diseases in the hatcheries and grow-out ponds and perfection of pond management principles are some of the fields in which active researches are being pursued in the region, there are several areas which need intensive studies and experimentation. One of the information often elicited relates to the minimum size of an economically viable ponds. The relationship between growth, survival, incidence of diseases, feeding efficiency, production rate of prawns and the size of the pond has not been clearly elucidated. In the context of development of prawn culture in small holdings with minimum inputs, investigations on this aspect has become an urgent necessity. Similarly, it is essential that a scientific basis for determination of stocking rate on a set of parameters of the conditions prevailing in the pond is evolved. At present, the stocking density rate ranges from 20,000/ha in simple culture operations carried out without using supplementary feeding to several hundred thousands per ha in intensive and controlled systems with supplementary feeding. But the basis on which such stocking rates are arrived at is seldom indicated.

Several interactive variable factors prevailing in the rearing medium in hatcheries and in the pond may affect the growth, survival, quality and production of prawns. While there is fairly good knowledge of the requirements of abiotic factors such as temperature, salinity and dissolved oxygen for the growth and survival of the important cultivable species of prawns, very little information is available on the role of various dissolved substances such as Ammonia, Nitrate, Nitrite, Carbon, Sulphur, Phosphorus, Calcium, Magnesium, Sodium, Chloride, Floride and Silicate in the rearing media of larvae and in the pond soil and their fluctuations on the well-being of prawns. Another aspect which needs further investigation is the rational application of supplementary feed in the fields when water exchange is through tidal currents and self-generating natural food is available to some extent to the stocked prawns. It is also essential that researches are intensified to develop low-cost feeds utilising plant proteins and vegetable wastes.

Documented studies on economics of prawn culture operations are scarce. Although, the culture operation is linked with and dependent on several factors such as the site, seed, feed, labour, the infrastructure facilities available and the socio-economic conditions of the place, it is imperative that reliable information on this aspect is made available to evaluate and propagate the system.

In an attempt to extend and establish prawn culture, efforts are made to introduce suitable species and to develop a stock for further propagation. Thus, exotic species of penaeid prawns are introduced into the Polynesian Islands where native cultivable species of prawns are not found. In recent years, Japan is endeavouring to develop 'Ocean ranching' by releasing large number of hatchery grown post-larvae (7-9 mm long) of *P.* (*M.*) *japonicus* on specially constructed artificial tide-lands from where they migrate to the sea and grow to commercial size to be caught by the fishing vessels.

The foregoing account outlines the trend of progress of research in penaeid prawn culture in the region during the past few years. It also indicates that the field is beset with many problems which call for intensive studies and concerted developmental, training and extension inputs to reap the maximum benefits.

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STATUS OF PENAEID SHRIMP FARMING IN THE U. S. A.

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ABSTRACT

Following an initial flurry of commercial shrimp farming trials in the U.S. all efforts to rear penaeid shrimp except one have failed economically and have stopped their operations. This discouraging situation following on the heels of about 10 years of intensive research and commercial development activity does not warrant an optimistic view of future U.S. shrimp farming prospects. Fortunately, this is neither the complete story nor the end of the story. U.S. commercial efforts have been closely tied to Central American shrimp farming activities in which some signs of profitability are visible. Also, research programmes are still under way, both in the U.S. and elsewhere, which continue to improve the technology for intensive culture of penaeid shrimp. Major advances in maturation and spawning, nutrition, and disease control have been made in recent years. Factors affecting the costs of harvesting wild shrimp (e.g. fuel costs) may influence prices of shrimp.

A brief analysis is presented of the basic reasons for failures of commercial efforts in the U.S. for the benefit of individuals considering similar ventures in the near future. Consideration is also given to the question of whether technology can be improved to the point that culture is profitable in the U.S. A comparison is made between penaeid shrimp farming and the farming of other high priced species such as trout presently being raised successfully in the U.S.

In conclusion the author addresses the issue of whether the U.S. experience with intensive culture of shrimp should be considered unique or whether the experience gained has important applications in other locations.

INTRODUCTION

THE STATUS of penaeid shrimp farming in the U.S. might be dealt with very quickly by saying that many attempts at commercial culture have been made, nearly all have failed and there is, therefore, no future for shrimp farming in the U.S. However, the story is not that simple, and in fact, the end of the story cannot yet be told. Interest in U.S. shrimp farming efforts by aquaculturists in other countries is centered upon the relationships between technical and business aspects in the U.S. and in their own countries. From this viewpoint the U.S. experience is important to shrimp farmers around the world and the future commercial efforts in the U.S. will be of considerable interest.

BACKGROUND

Following scientific advances with penaeid shrimp culture in Japan, the U.S. and elsewhere during the 1960's several commercial farming efforts were launched in the U.S. Most of these were initiated in either the late 1960's or the early 1970's and all but one have discontinued operations in the U.S. The U.S. efforts cannot be viewed independently from those in Central America because some firms shifted from U.S.-based pilot scale operations to participation in Latin American farming ventures, and some U.S. firms chose to begin operations in Central

America. Several of the Central American based firms have continued to operate and have played a major role in the improvement of shrimp farming technology. They are using technically sophisticated methods in their hatcheries, feed manufacture, disease control, and in maturation of captive broodstock.

A set of interacting factors made shrimp farming unprofitable in the U.S. in the 1970's. The principal factors were: the high cost of coastal land, the high cost of labour, the short growing season in ponds on the U.S. mainland, regulatory problems (e.g. effluent restrictions and limitations on use of public waters), poor growth of native U.S. shrimp species, poor food conversion with commercially available diets, and lack of a capability to mature and spawn adults in captivity. The rearing of wild juveniles or their entrapment for culture has never been practiced in the U.S. because it is illegal and fishermen utilizing natural stocks would not consider changes in the regulations. Therefore, hatcheries have always been a part of the shrimp farming activity in the U.S. A few of these negative factors might have been overcome, but in combination they posed an insurmountable obstacle to profitable production.

In spite of these problems, many investors and companies made the decision to go ahead with pilot or commercial scale trials. The price and market situation for penaeid shrimp provided a strong incentive, and U.S. investors were willing to take unusual risks in an attempt to become early participants in this new industry. In the early 1970's shrimp were being raised successfully in Japan for a speciality market and in Southeast Asia using tidal ponds and traditional methods. These successes encouraged Americans to believe they too could raise shirmp profitably. There were, of course, other investors who looked at the state of shrimp farming technology and decided not to invest at that time.

Those firms that shifted their operations to Central America or that initiated production there were more successful than the U.S. production efforts. Some efforts failed and several were sold, nevertheless progress toward profitable production was better in Central America.

An additional item of importance in the history of U.S. shrimp culture is the fact that a substantial part of the technological advances have been made by industrial groups. They have continuously refined their methods and conducted research oriented toward solving the problems encountered. A research base was provided by government and academic institutions in a number of countries and this research is continuing; however, major contributions have been made by corporations supporting the development effort and these contributions have been responsible for many of the significant advances in shrimp farming technology. A few of the specialised techniques remain company 'secrets' for a year or two, but as personnel move from one firm to another the 'secrets' become general knowledge.

Present Status

Only one of the firms which began commercial shrimp farming efforts in the U.S. is operating today. The firm still operating has managed to obtain funding to continue its operations although revenues from sales have been less than costs during every year of operation. The lack of commercial activity is not indicative of a lack of interest on the part of private and corporate investors and many interested parties are carefully watching the state of shrimp culture technology. Suitable land exists, in Texas for example, where penaeids can be raised during an 8-month period without heating the water. Tropical islands that are a part of the U.S. offer suitable temperatures throughout the year. The market situation for penaeid shrimp is probably more attractive today than it ever has been in the past with demand increasing but supplies for natural stocks stable.

Many of the constraints to commercial production in the U.S. still exist today, but some have been reduced. Non-native species have been accepted in the U.S. for at least experimental work and presumably for commercial production, commercial shrimp diets have been improved, adults of several species can be matured and spawned in captivity, and the general state-of-the-art has been improved in many small but significant ways. The experience U.S. firms have gained through their Latin American partnerships could be utilized in future U.S. efforts although generally favourable progress in Latin America is probably an indication that firms presently active there will continue to work in Latin America.

Research progress both in the U.S. and in many other countries is changing the level of biological and farming information available on penaeid shrimp. Progress on understanding nutritional requirements and development of feeds for all stages, description of environmental optima, inducement of maturation and spawning in captivity, selection of species best suited for culture, treatment of diseases, management of growout systems, and development of intensive culture systems with controlled environments has changed the technical status of shrimp farming considerably over the last 10 years.

The final point, intensive culture systems, is of major importance to the future of shrimp farming in the U.S., in the author's opinion. Research in the U.S. coupled with pilot production work in Mexico have been instrumental in moving intensive shrimp farming technology rapidly toward the level of technology used for raceway production of trout in the U.S. The value of shrimp is roughly double that of trout and the technical difficulties encountered are not markedly different. Our experience with shrimp is considerably less, and background scientific knowledge available is much less. An important consideration is that temperature control in intensive systems, largely with solar heating can make year round culture possible in the southern U.S. The engineering aspects of environmental control have largely been resolved. A second major consideration is that intensive systems can be operated without either large labour or land requirements, thus removing two of the additional constraints to shrimp farming in the U.S.

At least one commercial firm plans to begin shrimp production in the U.S. in the near future, and it is possible that a new phase of the U.S. shrimp farming industry is beginning. The author is predicting that profitable production of penaeids is in the not-too-distant future of the U.S. aquaculture industry and that highly intensive culture of shrimp will be the methodology most profitable under U.S. conditions.

Discussion

The purpose of this paper is not only to brief interested persons on the status of U.S. shrimp farming, but to examine the U.S. experience carefully to determine what may be gained by other countries presently expanding their shrimp farming operations or entering the field for the first time.

An important point is that many businessmen and investors misjudged the profitability of shrimp farming. Even though careful consultation with biologists, engineers and economists preceded their business ventures, they were unable to anticipate the seriousness of the problems encountered.

A second point is that investors typically wanted to establish their operation on a large scale rather than to conduct small-scale trials. The misconception prevailed that the firms entering the field early would have competitive advantages. This has not been the case and much money was wasted on large-scale trials.

A third point of importance is that our basic knowledge of penaeid shrimp was and is poor.

Thus far in this paper penaeid shrimp have been discussed as a group; however, this group is composed of a large number of species with widely varying habits, environmental requirements and foods. The species in this group are so different it has been suggested that an ecologically balanced polyculture could be developed using only a mix of penaeid shrimp species. It is essential to realise that results obtained with one species may not be replicable with a second species. The need for considerable adaptive research should be anticipated in most locations if locally available species are to be used. Some clearly superior species for culture (e.g. *Penaeus stylirostris* and *Penaeus monodon*) are emerging from the many tested.

A firm interested in intensive shrimp culture should be aware of the fact that a great deal of research and pilot-scale testing has been completed. Much of the resulting information is not published but is in the hands of individuals or companies who have conducted the trials. A comparison of methods used by firms presently continuing their ventures (e.g. in Central America) with those used by firms that have failed is particularly informative.

The distinction between animal husbandry (including aquaculture) with its many risks and an industrial or chemical process has not been grasped by many prospective investors in shrimp farming. Engineers or businessmen commonly have a poor understanding of the risks of disease, predation, the effects of weather or other variables common to animal husbandry. Intensive shrimp culture in its present state is more risky than most other forms of animal husbandry.

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INDUCED MATURATION OF PENAEID PRAWNS—A REVIEW

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Abstract

For hatchery production of penaeid prawn seed a steady supply of spawners is essential for effective planning of the operations. The uncertainty of procuring spawners from the wild has stimulated world wide interest in the efforts to induce penaeid prawns to mature under controlled conditions. The methods employed, research results achieved and the constraints encountered are reviewed critically in this paper.

Introduction

With the rapid expansion of panaeid prawn culture in many countries of the world, the need for producing large quantities of quality prawn seed under controlled conditions is keenly felt and hatchery systems are being developed. The biggest constraint in the hatchery production of prawn seed is the non-availability of adequate number of spawners of the desired species as and when required. Apart from Japan where there is a well organised trade in the capture and transport of live adult *Penaeus japonicus* from the sea, the securing of ripe spawners for the hatcheries is an uncertain and costly operation. Hence the highest priority in penaeid prawn culture research is given to work on the reproduction of the prawns in captivity (Conte, 1978). Efforts have been made in the past 10 years to induce the penaeid prawns, which normally mature and spawn only in the sea, to attain maturity under captive conditions. These research efforts are reviewed in this paper.

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Maturation in Captivity without Eyestalk Ablation

Although *Metapenaeus bennette* is known to breed in land locked coastal lakes (Morris and Bennett, 1952), the only report of natural reproduction of a penaeid prawn in a man-made earthen pond is that of Lichatowich *et al.* (1978) who obtained 50,000 postlarvae of *P. merguiensis* from a 0.2 ha pond filled with seawater filtered through a nitex mesh and stocked with adult prawns of this species. Silas *et al.* (MS) who collected mature females of *M. dobsoni* from the brackishwater culture ponds of the Prawn Culture Laboratory, Narakkal, Cochin, during the summer months when the salinity was 28-29 ppt, have made them spawn successfully in the laboratory and have reared the larvae using the pond water itself, thus proving that *M. dobsoni* can complete its life-cycle in the culture ponds during the high salinity months. However, no larvae have been collected from the pond itself so far.

A few instances of natural maturation and spawning of unablated, captive *P. monodon* in seawater ponds and tanks have been reported by Chen (1976) and Liao (1977) from Taiwan, by Primavera *et al.* (1978) from the Philippines, by AQUACOP (1979) from Tahiti. In Japan *P. latisulcatus* has spawned viable eggs in captivity without eye ablation (Shokita, 1970). Ryther (1979) observed that in China *P. orientalis* routinely matures in captivity. Primavera (1978 b) mentioned that at the SEAFDEC laboratories *P. merguiensis*, *P. indicus* and *Metapenaeus* spp. have attained natural maturity and spawned in 4 tonnes ferrocement tanks with running seawater facility. Patlan (1977, 1978 a, b, c) reported that at the Galveston Laboratories in the U.S.A. success has been achieved in making unablated *P. setiferus* attain maturiy in circular tanks and raceways where the environmental parameters were rigidly controlled. Although many spawnings were obtained the eggs were not fertilized as the females were not impregnated. Private prawn farmers in Central and South America are said to have succeeded in maturing *P. vannamei* and *P. stylirostris* in seawater ponds (Anon, 1977). The details of environmental conditions under which these results were obtained are not available.

However, some well documented reports of natural maturation and spawning of unablated penaeids in land-based maturation tanks are available. Laubier and Laubier (1979) and Caubere *et al.* (1979) from France have made *P. japonicus* mature and spawn in large circular tanks with flowthrough seawater system, by step-wise increase of temperature and photoperiod. In Mexico, Moore *et al.* (1974) have obtained maturation and spawning of *P. californianus* in raceways covered with inflated polyethylene bubble canopy. AQUACOP (1975, 1977 b, 1979) in Tahiti have succeeded in making *P. merguiensis*, *P. japonicus*, *P. stylirostris*, *P. vannamei* and *M. ensis* attain full maturity and spawn in circular fibreglass tanks with running seawater facility. At Conway in the U. K. Beard *et al.* (1977) have reared many generations of *P. merguiensis* in captivity in rectangular concrete tanks with subgravel filters. More details about these successful experiments are summarised in Table 1 and discussed in section 4 below.

Induced Maturation through Eyestalk Ablation

In many groups of decapod crustaceans the removal of eyestalks that contain the X-organ-sinus gland complex which produces and stores gonad inhibiting harmones has become a well recognised technique for inducing gonadial maturation (Adiyodi and Adiyodi, 1970). The application of this method in penaeid prawns was first started by Idyll (1971) and Caillouet (1973) in the U.S.A. on *Penaeus duorarum.* Bilateral eyestalk removal was also tried by Arnstein and Beard (1975) in the U. K. on *P. monodon* and *P. orientalis*, by AQUACOP (1975) in Tahiti on *P. aztecus*, by Santiago (1977) in Philippines on *P. monodom* and by Muthu and Laxminarayana (1980) on *P. indicus* and *P. monodon*. The results were identical in all these experiments : the initial mortality was very high but in the prawns that survived, full development of the gonads was observed within 5-14 days of eyestalk removal ; however, spawning did not take place and the ovaries regressed gradually and the prawns died within a month ; loss of balance and spiral swimming behaviour were also observed. The present authors also found that the colour of the ovary of bilaterally ablated females was pale and never attained the dark olive green colour seen in wild spawners. The only report of successful spawning of bilaterally ablated penaeid prawns is that of Alikunhi *et al.* (1976) from Indonesia who stated that *P. merguiensis* and *P. monodon* spawned after bilateral eyestalk removal, the eggs of the former species even developing into normal postlarvae while the eggs of the latter were unfertilized.

Duronslet *et al.* (1975) using electron microscope to study the sequence of development of the oocytes in the ovary of bilaterally eyeablated and normal females of *P. aztecus* and *P. setiferus*, found that the process is identical in the experimental and normal individuals; but the ablated females after reaching full ovarian growth never spawned and the gonads regressed. Their most interesting observation, however, was that, although the oocytes from ablated animals demonstrated normal growth, they did not undergo meiosis. Unfortunately this important point has not been elaborated by them.

The high mortality and inability of the females to spawn after bilateral removal of eyestalks, prompted the research workers to abandon this method. After Arnstein and Beard (1975) found that full development of ovaries and good survival could be achieved in *P. orientalis*, *P. occidentalis* and *P. monodon* by the removal of only one eyestalk, unilateral eyestalk ablation was used successfully in many countries to induce maturation and spawning of captive penaeids (AQUACOP, 1977 a, 1979; Wear and Santiago, 1976; Santiago, 1977; Primavera, 1978, a, b; Primavera *et al.*, 1978; Primavera and Yap, 1979; Rodriquez, 1979; Halder, 1978, 1980; Muthu and Laxminarayana, 1979, 1980; Lumare, 1979). The results of these nvestigations are summarised in Table 2 and discussed in the following sections.

Methods of eyestalk removal: The simplest way is to cut the eyestalk near its base with a pair of sharp scissors (Arnstein and Beard, 1975; Lumare, 1979). However, this leads to profuse bleeding and in delicate species, such as *P. indicus* results in high mortality. Caillouet (1973) used a pair of scissors and immediately cauterised the wound with a pencil type soldering iron to avoid loss of blood. Muthu and Laxminarayana (1979, 1980) used a medical electrocautery apparatus to remove the eyestalk. In this method, while cutting the eyestalk the wound is simultaneously sealed, resulting in cent percent survival. To simplify the ablation procedure, Primavera (1978 a) incised the eyeball with a sharp blade, allowed the fluid to ooze out and then squeezed the contents of the eyeball outwards between the thumb and forefinger and crushed the eyestalk 2-3 times to destroy the tissue. For rapid ablation of large numbers of *P. monodon* for stocking in marine pens, Rodriquez (1979) simply squeezed out the contents of the eyeball and crushed the eyestalk by pressing between the fingers. This method is suitable only for hardy species like *P. monodon*. The present authors encountered heavy mortality in *P. indicus* ablated by this method.

Latency period: The time taken by the females to attain full maturity after eyestalk ablation varies considerably (Table 2.) Maturation appears to be faster (5-10 days) in white prawns such as *P. merguiensis*, *P. indicus*, *P. vannamei* and *P. stylirostris*, than in *P. monodon* and *P. aztecus* (average 3 weeks). It also appears to depend upon the season. Lumare (1979) found that ablated *P. kerathurus* kept at a constant temperature of 25°C took 43-69 days to attain maturity during November-December; 30 days in March and only 10 days in May-June *i.e.*, they appear to mature faster as their natural breeding season is approached. Size also appears to have a bearing on the time taken to attain maturity; the larger ones which are perhaps physiologically ready for maturation respond to the eyestalk ablation treatment faster than the smaller ones.

Rematuration: Ablated female prawns repeatedly remature and spawn viable eggs. Tagging of ablated female *P. monodon* at the SEAFDEC, Philippines showed that of a given number of females that spawned once, 14% spawned a second time, 3% a third time and 0.8% a fourth time (Primavera, 1978 b). A subsequent spawning may take place as quickly as 3-5 days after the preceeding one (Primavera and

Borlongon, 1978; Primavera *et al.*, 1979). In Tahiti, AQUACOP (1979) reported that six *P. monodon* gave 18 spawnings in three months; one of them spawned 3 times within 2 weeks without moulting. Lumare (1979) observed that *P. kerathurus* spawned upto 8 times after eyestalk ablation at intervals of less than 10 days; no reduction in the number of eggs was noticed with repeated spawning. The present authors found that one ablated *P. indicus* spawned 5 times at intervals of 13, 12, 11, 18 and 26 days, although viable nauplii were obtained only on one occasion.

Impregnation: It is well-known that in penaeid prawns mating and spawning are independent processes. Under natural conditions mating in the case of penaeids with closed thelycum takes place between a hard (intermoult) male and a soft (freshly moulted) female which stores the spermatophore received from the male in its thelycum. Spawning takes place in the absence of the male, the female herself releasing the sperms from the thelycum at the time of oviposition. So, for obtaining fertilized eggs the female should be impregnated. But in captivity an unimpregnated female can be induced to mature and spawn after eyestalk ablation, but the eggs won't be fertilized. To avoid this, ablation of eyestalk should be done on impregnated females only. Hence making the prawns mate successfully in captivity is as important as inducing the females to develop the ovary. In actual practice it is easier to achieve the latter than the former (Arnstein and Beard, 1975; Patlan, 1977, 1978 a, b, c). It is especially difficult in the penaeids such as *P. setiferus*, *P. vannamei* and *P. stylirostris*. AQUACOP (1979) found that the percentage of impregnated females could be increased by keeping the males and females in separate tanks and introducing only the ripe females into the male tank. Separation seems to increase the attraction between the sexes. Perhaps even in the penaeids with closed thelycum the impregnation rate could be improved, by keeping the males and females in separate tanks and introducing the female which is about to moult, into the male tank.

Factors that Affect the Maturation Process

The physiological and environmental factors that influence maturation in penaeid prawns are discussed here.

Eyestalk principle: The fact that bilateral eyestalk ablation usually does not lead to spawning and our observation that the ovary of the bilaterally ablated female is pale in colour suggest that the eye is in some way necessary for normal ovarian growth and for triggering the spawning reflex. Maturation of ovaries is said to be stimulted by the gonad stimulating harmones secreted by the brain and the thoracic ganglia and inhibited by the Gonad Inhibiting Harmone (GIH) of the eyestalk (Adiyodi and Adiyodi, 1970). But the very fact that, in nature, the prawn is able to mature and spawn with both eyes intact suggests that the antagonism of the eyestalk principle may be reduced by a decline in the titre of the GIH as the prawn grows and moves into an environment suitable for spawning and the final spawning act may, in fact, be triggered by a stimulus, either visual or harmonal, originating in the eyestalk. In unilateral eyestalk ablation the titre of the GIH is artificially lowered and this appears to stimulate vitellogenesis.

Age: Successful maturation and spawning of *P. monodon* was obtained by ablating females that were 15 months old (Santiago, 1977), 8 month old (AQUACOP, 1977) and 5 months old (Primavera, 1978 a). However, the quality of the eggs produced by the 5 month old pond-reared females is considered to be inferior to the eggs produced by 1-2 year old wild females (Primavera, per. comm.) Females of the same size differ widely in age, depending upon the conditions under which they have grown (Primavera, 1978 b). She feels that given the same body size (minimum of 90 gm) wild females are older and therefore more responsive to induced maturation than pond reared females at norml harvest age of 4-5 months. However, the age at which the females mature in captivity varies with the species. AQUACOP (1975) found that *P. merguiensis* spawned after 4-5 months, *Metapenaeus ensis* after 8 months and *P. japonicus* and *P. aztecus* after one year. Beard *et al.* (1977) reported that the age of female *P. merguiensis* at first maturation was 6-7 months.

Food: Caillouet (1973) fed unablated *P. duorarum* with diets to which additives such as beta carotene, phosphotidylcholine, cholesterol, DL alpha tocopherol, calciferol and 17 beta estradiol were added; but the prawns did not attain maturity.

In most of the successful experiments (Table 1, 2) the captive broodstock has been fed *ad libidum* on fresh mussel, oyster or clam flesh. However, Primavera *et al.* (1979) reported that better results were obtained when the prawns were fed mussel flesh in the morning and pelletised feed in the evening. AQUACOP (1979) observed that among the different compounded pellets tested, the best ones were high protein diets (60%) containing squid meal. They also reported that if the females are isolated and allowed to complete the ovarian development in separate tanks where a supplement of fresh Trocha flesh is given, the quality of the eggs spawned is much better. Molluscan flesh in some way seems to be good for gonad development. The present authors have observed that the visceral masses of the clams used for feeding the brood stock, generally contain developing gonads which probably provide the right type of fatty acids and lipoproteins essential for vitellogenesis in the maturing prawns.

Stress; Any sort of physiological stress, due to overcrowding, frequent handling or poor water quality, delays the maturation process or causes regression of developed ovaries. *P. monodon* is especially sensitive in this respect (AQUACOP, 1979). To reduce handling stress while checking the prawns for determining the stage of maturation, the prawns are examined at night using an underwater flashlight tied to a pole and held close to the prawn so that the light strikes perpendicular to the upper part of the body when the dark green, mature ovaries show up very well (Primavera, 1978 b; AQUACOP, 1979).

From Table 1 and 2 the stocking density in the maturation tanks is found to vary from 3-7 animals per m^2. The lower density is preferred for the larger species such as *P. monodon*. The highest density used was $20/m^2$ in the case of the small sized *P. merguiensis* in Tahiti. AQUACOP (1979) report that in their broodstock tanks maturations are rare and spawning does not occur if the biomass of prawns in the tanks exceeds 300 gm/m^2.

Poor water quality in ill maintained pools is a major source of stress to the prawns. If the uneaten food, moults, and faecal matter in the pools are not removed daily, the water quality deteriorates rapidly as decay of these substances, apart from releasing toxic substances, increases the biological oxygen demand of the water. Under such circumstances the intake of food by the prawns declines markedly (personal observations). Another source of stress is the accumulation of the toxic ammonia excreted by the prawns themselves. Ammonia toxicity in penaeid prawns has been studied by Wickins (1976 a) who states that the maximum acceptable level of ammonia concentration is 0.1 mg NH_3-N/ litre. This value may apply to normal maintenance and growth of prawns in culture systems but a still lower ammonia level may be required by the prawns for successful maturation. All the recirculating systems and flowthrough facilities referred to in Tables 1 and 2 are mainly designed to prevent

TABLE 1. *Summary of results of experiments on maturation of penaeid prawns in captivity without eyestalk ablation*

Authors	Type and size of the container	Water management	Stocking density Nos/m²	Sex ratio M : F	Temp. (°C)	Salinity (‰)	pH	Light	Feed	Species	Time taken to reach maturity
AQUACOP (1975, 1977 b, 1979)	4m dia. Fibreglass tanks with 1 m water depth. Water fed through perforated concentric PVC tubes embedded in gravel bottom and covered with coral sand; water drained through central stand pipe.	Flow-through water exchange rate 2-3 times/day	20 for *P. merguinesis and M. ensis* 6.6 for *P. vannammei and P. stylirostris*	1 : 3 or 1 : 1	25.5 to 29.0	34.5	8.2	Natural daylight. Tanks covered with synthetic material to allow only 10 to 40% of incident light.	Pelletised feed supplemented with squid flesh	*P. merguiensis* *P. japonicus* *P. stylirostris* *P. vannemei* *M. ensis*	3-4 weeks
Beard *et al.* (1977)	Concrete tank 2.9 x 1.65 x 0.3 m inside a heated hut with clear PVC roof. Half the bottom area covered with a sub-gravel filter with air-lift recirculation	50% of water renewed each week	5	1 : 1 or 1 : 2	25 to 31	30-36	7.5 to 8.5	1000 to 3,000 lumens per m²	Fresh mussel and frozen shrimp	*P. merguiensis*	Repeated spawning every 2.6 months
Caubere *et al.* (1979)	5 m dia. concrete tank with 1.2 m water depth. Provided with air-lift recirculation and double bottom	Flowthrough at 200 litres per hour	4	1 : 3	Step-wise increase from 15 to 24 over a 3 month period	30.5 to 36.0	7.5 to 8.5	4,000 lux step-wise increase from 8 to 16 hrs/day over a 3 month period	Fresh oysters and mussels	*P. japonicus*	3 months
Laubier and Laubier (1979)	2.9 m concrete tank; 1 m water depth; with double bottom and air-lift recirculation	Flowthrough at 450 litres per hr. exchange rate 150% per day	7.5	1 : 1	Increased from 15°C on 21st Apr. to 24 on 21st June	sea-water	8.1 to 8.3	2,000-6,000 lux., photoperiod increased from 12½ to 14½ hrs/day over a period of 11 weeks	Fresh mussel	*P. japonicus*	3 months
Moore *et al.* (1974)	23 × 3 × 0.6 m raceway under inflated polyethylene bubble canopy	Flowthrough exchange rate 700% per day	6.4	1 : 1.6	22-28	sea-water	8.0 to 8.3	20 % of natural light	Flaked food	*P. californianus*	4 months

TABLE 2. *Summary of results of experiments on captive broodstock after unilateral eyestalk ablation*

Authors	Type and size of containers	Water management	Stocking density Nos/m²	Sex ratio M : F	Temp. (°C)	Salinity (‰)	pH	Light	Feed	Species	Time taken to reach maturity after eyestalk ablation (days)
AQUACOP (1977 a, 1979)	Same as AQUACOP (1975) vide Table 1	Flowthrough water exchange 2-3 times/day	3.3	1 : 1	25.5 to 29.0	34.5	8.2	Natural day light 10-40% of incident light	pelletised feed	*P. monodon*	21-28
Arnstein and Beard (1975)	Rectangular fibreglass tanks, 86 × 76 × 25 cm ; with subgravel filter and air-lift recirculation at 8-9 litres/minute	50% of water replaced every week	6	1 : 1	20+2	28-30		Subdued artificial light ; phootperiod 8 hrs/day	Fresh mussel and frozen *Crangon*	*P. orientalis*	12-14
Halder (1978, 1980)	Nylon net cages kept in a 200 m² brackishwater ponds 2 m deep	Flushed by tides	..	1.6 : 1	Increased from 22.4 to 26.4	Increased from 15 to 25		Natural daylight	Prawns and trash fish	*P. monodon*	40
Lumare (1979)	2 × 2 × 1 m cement tank, with subsand filter, kept in a green house, recirculation at 6 times water vol. in 24 hrs.	1/3rd of water replaced everyday	10 to 15	1 : 1.1 to 1 : 5.9	25	36	7.8 average	Natural daylight and photoperiod	fresh mussel	*P. kerathurus*	43-69 in Nov-Dec./ 30 in Mar., 10 in May-June.

Muthu and Laxmi-narayana (1979, 1980)	3.6 m dia. plastic lined pools with subgravel filter and air-lift recirculation	Water changed when the clarity declines	5	1 : 1	24.5 to 30.2	27.0 to 36.0	ave-rage 7.9	Natural daylight inside a tile covered shed without side walls	fresh and frozen clam meat	*P. indicus* *P. monodon* *M. dobsoni* *Parapenaeo-psis stylifera*	10-16
Primavera (1978 b)	4 m. dia. ferrocement tank 1-1.5 m water depth (Tolosa, 1978)	Flowthrough water exchange rate 2-4 times/day	4-7	1 : 1 or 1 : 2	..	..	..	tanks co-vered with black cloth so that light inten-sity is re-duced by 40% to 60%	Mussel flesh in the morning and pellets in the evening	*P. mono-don*	7 days to 2-3 months av. 21
Primavera (1978 a)	Concrete tanks 4.85×4.85 ×1 m under transparent plastic roof. Aeration by air stones	Water changed only once a week	4	1 : 1	23.8 to 26.2	30-34	7.8 to 8.1	Natural light filter-ing through plastic roofing	Fresh mussel flesh	5 months old pond reared *P. mono-don*	21
Primavera *et al.* (1978)	Concrete tanks 7.25 × 7.25×1 m under trans-parent plastic roof	Flowthrough tank emptied and water completely changed every 5-6 days	7	1 : 1	23.5 to 26.8	30-34	7.8 to 8.0	-do-	-do-	*P. mono-don*	11-25
Wear and Santiago (1976) Santiago 1977), Rodriquez (1979)	250 m² marine pens in a sheltered tidal cove in 4-6 m depth	flushed by the tides	1.2 to 1.6	1 : 1 or 1 : 2	27.1 to 30.7	31.5 to 34.6	—	Natural daylight	-do-	*P. mono-don*	7-60

the accumulation of ammonia and to maintain the quality of the seawater in the pools. The recirculating sytems employ some form of biological filter which aerobically oxidizes ammonia to harmless nitrates through the action of the nitrifying bacteria growing on the surface of the filter material (Spotte, 1970). Vigorous aeration is used to maintain the oxygen concentration in the pools at near saturation levels and to operate the air lifts in the recirculation systems.

Salinity: The fact that penaeid prawns which live as juveniles in brackishwaters migrate to the sea for spawning purposes, suggests that salinity is one of the important factors that affect the maturation process. This is supported by the observation of Silas *et al.* (MS) that *M. dobsoni* attains full maturity in the brackishwater ponds when the salinity increases to 28-29 ppt. Even *P. indicus* in stage III of maturity have been collected by George (1974) from the brackishwater ponds during the high salinity months. From Tables 1 and 2 it is seen that the penaeids have attained full maturity and spawned in salinities ranging from 27-36 ppt. The only exception was reported by Halder (1978, 1980) who stated that ablated *P. monodon* attained maturity and spawned viable eggs in a brackishwater environment when the salinity was 25 ppt.

pH: Best results were obtained when oceanic water at a steady pH of 8.2 was continuously made to flow through the maturation pools (AQUACOP, 1975, 1977 a 1979). In recirculation systems pH declines rapidly due to the physiological activity of the organisms present in the pool and may become a limiting factor when it reaches 7.3 (Wickins, 1976 a). Reduction in pH and depletion of inorganic carbon in the water, which is said to affect the calcification of the cuticle and the normal moulting process, are direct consequences of bacterial nitrification of ammonia to nitrates in a biological filter (Wickins, 1976 b). So a completely closed system of recirculation is not feasible; at least part of the water has to be replaced by fresh seawater periodically or required amounts of sodium carbonate or bicarbonate should be added regularly to maintain the quality of the water.

Temperature: Laubier and Laubier (1979) kept *P. japonicus* in three different tanks in which the temperature was increased from 15 to 20°C, 15 to 24°C and 15 to 26°C respectively over a period of 11 weeks and found that the largest number of spawnings occurred in the tank having a temperature of 24°C. Caubere *et al.* (1979) showed that if the temperature is increased from 15 to 24°C over a period of 3 months, maturation was accelerated and spawnings took place after 3 months, whereas in a tank where the temperature was allowed to increase naturally from 15 to 24°C over a 6 month period the maturation process was delayed and spawning occurred only after 6 months. It is significant that these two experiments were performed in sub-tropical region. In the tropics temperature does not appear to be a limiting factor and penaeids had attained maturity in temperatures ranging from 22°C to 31°C (Table 1 and 2).

Light: The influence of photoperiod on maturation of unablated *P. japonicus* has been studied by Laubier and Laubier (1979) and Caubere *et al.* (1979) and in unilaterally ablated *P. kerathurus* by Lumare (1979). Laubier and Laubier (1979) found that more spawnings occurred in a tank where the light period was increased from 12½ hours/day to 14½ hrs/day over a period of 11 weeks. Caubere *et al.* (1979) observed that best maturaration and spawning occurred when the light period was increased from 8 hrs/day to 16 hrs/day over a 3 months period. However, in these two experiments the temperature was also gradually increased over the same period from 15°C to 24°C. So it cannot be assessed whether the accelerated development of gonads was due to increase in photoperiod or due to increase in temperature. However, Lumare's (1979) experiment in which the temperature was kept constant at 25°C and the photoperiod varied, suggests that increase in photoperiod from 13 hrs/day in March to 16 hrs/day in May-June might have accelerated the maturation process. Even here the evidence is not conclusive since the difference in the seasons might have influenced the results, as May-June was their natural spawning season. This doubt is further strengthened by the fact that during Nov.-Dec. maturation was faster at 9 hrs of light/day than at 12 hrs of light/day. So the effect of photoperiod on maturation is not fully understood.

On the other hand there seems to be sufficient evidence to conclude that a reduction in the intensity of the light to about 10% of natural day light has a beneficial effect on the maturation process (Table 1, 2).

Caillouet (1973) studied the effect of coloured light on maturation in unablated *P. duororum* and got negative results with blue, green and white light. Alava (1979) experimented with blue, red and natural light on unablated *P. monodon* and found that they did not attain full maturity in any light; however, under blue and natural light prawns with stage III ovaries were obtained while those exposed to red light reached only stage II.

Pressure : Only Caubere *et al.* (1979) have tried to study the effect of pressure on spawning. Mature females subjected to a pressure of 2.5 kg/cm^2 for 12 hrs spawned. But mature females spawned even without subjecting them to increased pressure. Pressure does not appear to have any effect on the maturation process either, since Beard *et al.* (1977) have obtained full maturation of gonad in unablated *P. merguiensis* grown in a tank with only 0.3 m depth of seawater.

Size of the maturation pool : The present authors found that ablated *P. indicus* and *P. monodon* did not attain maturity when kept in 1.8 m dia pools whereas they matured well in 3.6 m dia pools. Primavera (1979) opined that the mating behaviour of *P. monodon* calls for a large pool with sufficient area for swimming about freely, if impregnation is to take place normally. Arnstein and Beard (1975) also found that although *P. orientalis* attained maturity in 0.6 m^2 fibreglass tanks, they were not impregnated. Good results have been attained in maturation tanks which exceeded 4 m^2 in area (Table 1, 2). The large marine pens used in Philippines for maturation of ablated *P. monodon* are no doubt very good. But the difficulty of getting a suitable sheltered site for constructing the pens near a hatchery and the short life of the bamboo pens and the consequent high cost of frequent renewals and the difficulties involved in sampling the prawns from the pens, are some of the disadvantages that make this system less popular. On the other hand the land based maturation facilities referred to in Tables 1 and 2 can form part of the hatchery, making use of its aeration and seawater pumping facilities.

CONCLUSION

It is now evident that many penaeids can be made to mature and spawn in captivity without eyestalk ablation in raceways and concrete tanks with running seawater facility or in open recirculating seawater systems. It is essential that the water quality be maintained as close to that of good open seawater as possible. Some of the species which do not easily attain maturity in captivity can be induced to mature by unilateral eyestalk ablation. Some basic information on the factors that affect the maturation of the ovary are available. However, more research is needed to understand (i) the harmonal control of maturation in penaeid prawns, (ii) the effect of dietary factors on maturation.

(iii) the factors that promote mating in captivity and (iv) the effect of photoperiod on reproduction. Technological improvements to reduce the cost of construction of the maturation pools, seawater supply systems and water purification systems are also urgently needed.

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STUDIES ON BROODSTOCK OF SUGPO *PENAEUS MONODON* FABRICIUS AND OTHER PENAEIDS AT THE SEAFDEC AQUACULTURE DEPARTMENT*

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ABSTRACT

For hatchery production of *Penaeus monodon* and other penaeid fry, the SEAFDEC Aquaculture Department is dependent mainly on captive broodstock in the form of ablated females, using up to 1,500 spawners in one year. The availability of such broodstock has enabled us to gather information on the reproductive biology as well as broodstock techniques for *P. monodon* and other species. This paper discusses studies on courtship and mating behaviour, fecundity, egg quality and rematuration ; and requirements for induced maturation (source and age of stock, sex ratio, feeding, tank management, etc.) of *P. monodon*. A comparison of biological and construction requirements of two broodstock systems — land-based tanks and marine pens — is made. Work on other penaeids, mainly *P. indicus* is discussed. Lastly, areas for future research on penaeid maturation are highlighted.

INTRODUCTION

RESEARCH on penaeid prawns at the SEAFDEC Aquaculture Department dates back to 1974 when the first batch of *Penaeus monodon* postlarvae was transported by air from the Mindanao State University Marine Research Laboratory, a pioneering aquaculture research institute in Naawan, Misamis Oriental (Villaluz, *et al.*, 1972) to brackishwater ponds at the Leganes, Iloilo station of the Department.

In the five years that have passed, the Department has established big-tank prawn hatcheries in the main Tigbauan station and small-tank hatcheries at Tigbauan and Leganes, Iloilo ; Batan, Aklan ; and Zamboanga City.

The first sugpo spawners used in the Tigbauan hatcheries in 1975 were caught from the sea and a heavy dependence on wild spawners, up to 95% of total supply, characterised hatchery operations for the first two years. At the same time, ablation experiments to induce maturation in captive *P. monodon* were started. Although the life-cycle of *P. monodon* was completed in the Igang maturation pens in December 1975 (Santiago, 1977), the mass production of spawners by unilateral eyestalk ablation was achieved only in 1977 with the installation of maturation pens in the Batan substation. It was also in 1977 that maturation of *P. monodon* in land-based tanks was started. Most of the research work on penaeid maturation has been undertaken in these tanks rather than in maturation pens because of greater control of experimental variables.

BROODSTOCK STUDIES

A. *Reproductive biology*

(1) *Courtship and mating :* *P. monodon* belongs to the group of penaeids with a closed thelycum. Moulting of the female is a prerequisite to mating because insertion of the

* Contribution No. 58 of the SEAFDEC Aquaculture Department.

spermatophores can only take place when the thelycum is soft. Courtship and mating behaviour may be divided into three distinct phases (Primavera, 1979 a).

The newly-moulted female attracts up to three males who follow her around, but only one male is able to position himself directly below the female. As the pair swims in tandem, the male turns ventral side up trying to align his thorax with that of the female. Once successful, the male turns perpendicular to the female, curves his body in a U-shape around her and flicks head and tail simultaneously up to three times in a row, all these steps in quick succession. The whole process may last from 30 min. to 3 hours. Information on copulatory behaviour is important in establishing minimum physical dimensions of broodstock tanks.

(2) *Ovarian maturation stages:* Based on external examination and dissection of the ovaries of wild and ablated *P. monodon* females, the following maturation stages have been described (Alava, 1979 ; Primavera, 1979 a) :

(*a*) Stage I (Immature) : Ovaries thin, transparent and not visible through the dorsal exoskeleton. On dissection they appear as colourless strands of tissue, devoid of visible eggs. (In actual sampling operations, this is called Stage 0).

(*b*) Stage II (Early maturing) : Ovaries observed as a thin, linear band through the exoskeleton as they start to increase in size, particularly in the anterior and middle lobes. Dissected ovaries are firm and smooth with colour ranging from cloudy white to light brown and grayish-green. (In actual sampling operations, this is divided into Stage I for ovaries that appear as a very thin band through the exoskeleton and Stage II for ovaries that are relatively thicker).

(*c*) Stage III (Late maturing) : Ovaries visible through the exoskeleton as a thick, solid, dark linear band as they considerably expand from the anterior thoracic to the posterior abdominal region. A slight ' diamond ' or ' butterfly ' can be seen at the level of the first abdominal segment. Dissected ovaries are compact, granular in texture with clumps of eggs and mostly light-olive green.

(*d*) Stage IV (Mature or ripe) : The diamond-shaped expansion at the anterior abdominal region is larger and distinct ; the linear band is thicker. Upon dissection, the ovaries appear dark olive-green, compact, granular and are so distended, they fill up all available space in the body cavity.

(*e*) Stage V (Spent) : Completely spent ovaries outwardly appear similar to Stage I (Immature) ovaries. Dissected ovaries are flaccid and yellowish. Partially spent ovaries have either the anterior or posterior ovarian lobes remaining unspawned.

(3) *Spawning:* Most female *P. monodon* spawn between 9.00 p.m. and 2.00 a.m. and a spawning may last from 2 to 7 min. The eggs (and sperm) are released, often forcefully, as the female swims upward in circles and may continue even as she returns to the bottom. Ovarian material is released into the water together with the eggs. Aeration in the spawning tank causes this material to form bubbles covering the whole water surface. After a few minutes, the bubbles break up, completely disappearing within half an hour after spawning. The material turns into scum which forms a thin to very thick orange ring along the sides of the spawning tank. Around 75% of all spawnings are complete, the rest are partial with some of the eggs retained in the ovaries.

(4) *Fecundity:* The number of eggs produced in a complete spawning ranges from 200,000 to one million with an average of 500,000 eggs for *P. monodon* spawners caught from the wild. For ablated females, the range

is 100,000 to 800,000 with an average of 200,000 for ablated pond stock and 300,000 for ablated wild stock.

(5) *Egg quality:* Based on morphological observations and hatching rate, eggs of wild, ablated pond stock and ablated wild stock *P. monodon* can be classified into five egg types (Primavera and Posadas, MS).

The normal or 'good' eggs belong to Type A_1 with an average hatching rate of 58% and healthy nauplii. In contrast, Type A_2 eggs are 'not so good' with a lower hatching rate of 32% and many weak and abnormal napulii. Types B, C, and D are 'bad' eggs which are all unfertilized and do not hatch. Irregular formations caused by the flowing out of the cytoplasm characterise type B eggs. Type C eggs are unfertilized eggs that do not change in appearance with the cytoplasm remaining a single mass while type D eggs have very little cytoplasm left due to massive bacterial invasion.

Eggs from wild spawners have the highest proportion of A_1 eggs (49%) followed by ablated wild stock females (39%) and ablated pond stock (24%). Clearly, ablated females of pond stock produce eggs of inferior quality compared to other groups of spawners.

There is a highly linear relationship between the proportion of A_1 eggs and percentage of hatching rate (% H.R.) ($P<0.01$) for ablated *P. monodon* with $\%\ H.R. = 0.064 + 0.796\%\ A_1$ for pond ablated females and $\%\ H.R. = 2.682 + 0.724\%\ A_1$ for wild ablated females. If a 30% hatching rate is accepted as the minimum level for hatchery operations, spawnings should have at least 38% A_1 eggs to get this hatching rate for both pond ablated and wild ablated females.

(6) *Rematuration:* Tagging prawns with consecutively numbered brass tags around the unablated eyestalk immediately after the first spawning (Rodriguez, 1976) makes it possible to keep complete records of individual females including fecundity and hatching rate of consecutive spawnings, number of days between spawnings, etc. Data over a three-year period show progressive improvement in rematuration rates for ablated females (Table 1). Given 100 ablated females that spawned a first time, on the average, 10 of them had a second spawning in 1977 (Primavera and Borlongan, 1978), 11 in 1978, and 23 in 1979.

The main factor that accounts for low rematuration rates is a high rate of spawner mortality. In 1977, a newly-spawned *P. monodon* survived an average of only 9 days compared to 2½ weeks in 1978. As spawner mortality decreased, rematuration rates may be expected to improve.

B. Management studies

(1) *Source and age of pond stock*: Ablation of hundreds, even thousands, of females has led to the observation that ablated *P. monodon* wild stock give a better performance in terms of higher fecundity and hatching rate, better egg quality and lower mortality compared to ablated pond stock (Primavera and Yap, 1979) as shown in Table 2.

The problem then is how to make pond stock females perform equally well as wild stock after ablation. Our present hypothesis is that given the same body size (minimum of 90 g), wild females are older, and therefore more receptive to induced maturation than pond-reared females at normal harvest age of 4-6 months. Data from past studies using pond stock show that the only successful rearings up to the postlarvae are from spawnings of females ablated between one to two years of age (Table 3). One approach would then be to age pond stock females to at least one year prior to ablation.

(2) *Sex ratio:* Up to 1979, initial stocking of *P. monodon* in maturation tanks and pens

TABLE 1. *Data on number, fecundity and hatching rate of first and subsequent spawnings of tagged ablated* Penaeus monodon *from both pond and wild stock at the SEAFDEC Aquaculture Department Tigbauan, Iloilo station over a three-year period*

	1977	1978	1979
No. (%) spawnings			
1st spawnings ..	316 (100%)	230 (100%)	185 (100 %)
2nd spawnings ..	33 (10.4%)	32 (13.9%)	43 (23.2%)
3rd spawnings ..	5 (1.6%)	9 (3.9%)	11 (5.9%)
4th spawnings ..	0	1 (0.4%)	0
Ave. no. eggs spawning			
1st spawning ..	164,000 (99)*	203,102 (158)	282,000 (185)
2nd spawning ..	182,993 (20)	190,859 (28)	275,000 (43)
3rd spawning ..	140,000 (4)	127,689 (9)	173,000 (11)
4th spawning ..	..	97,650 (1)	..
Ave. % hatching rate			
1st spawning ..	no data	30.5 (158)	34.4 (185)
2nd spawning ..	36.7 (19)*	34.3 (28)	27.6 (43)
3rd spawning ..	34.8 (4)	5.3 (9)	14.4 (11)
4th spawning ..	..	52.5 (1)	..
Ave. no. days survival after 1st spawning ..	9.2	17.0	no data

* Figures in parenthesis refer to number of females.

TABLE 2. *Comparison of survival and maturation in broodstock tanks of ablated* Penaeus monodon *from pond and wild sources**

	Pond stock	Wild stock
% mortality/month		
male ..	22 (380)	6 (112)
female ..	58 (270)	14 (248)
% spawners/month ..	24 (200)	20 (248)
Ave. no. eggs/spawning ..	204,400 (111)	270,000 (213)
Ave. % hatching rate ..	20 (111)	36 (213)
Ave. % rematuration**		
no. 1st spawnings ..	123	213
no. 2nd spawnings ..	28 (22.8%)	41 (19.2%)
no. 3rd spawnings ..	7 (5.7%)	12 (5.6%)
no. 4th spawnings ..	1 (0.8%)	0 (0%)

* Figures in parenthesis refer to number of individuals.

** Data taken from 1978-79 records of tagged spawners.

at a 1 : 1 sex ratio (Primavera, 1979b; Rodriguez, 1979) has been based on an assumed safety factor rather than on experimental data. In a study on different sex ratios, the 1 male : 2 female ratio produced the highest percentage of spawnings, highest average fecundity and the greatest total number of eggs (Table 4) (Alava and Primavera, MS). We now routinely stock our tanks at an initial 1 male : 2 female ratio which is economical because it maximizes the number of females per tank. Moreover, the higher mortality rates of females (due to additional sampling and spawning stress) compared to males gradually leads to more balanced numbers of both sexes after two months.

As expected, all-female population produced many eggs but no nauplii because of a zero hatching rate (Table 4). In the absence of males, the females had no spermatophores and the spawned eggs remained unfertilized.

(3) *Feeding:* Four different feeding regimes combining pellets, frozen mussel and frozen squid were given to ablated pond stock *P. monodon*. Average fecundity and hatching rate and total number of spawnings, eggs and nauplii produced were highest for the mussel-pellet combination followed by the mussel-mussel regime (Table 5) (Primavera *et al.*, in press).

Standard feeding for our prawn broodstock is shelled frozen brown mussel *Modiolus metcalfei* in the morning and commercial pellets in the afternoon.

(4) *Ablation method:* The standard eyestalk ablation method for tank broodstock involves incision of the eye followed by a crushing of the distal eyestalk tissue (Primavera, 1978); mortality within one week after ablation averages 5-10%. Ablation in the pens where hundreds of females may be ablated at one time, involves a squeezing of the eyestalk simultaneous with the pinching out of the contents of the eye (Rodriguez, 1979).

(5) *Substrate:* The substrate in our tanks has been white coralline material (Primavera, *et al.*, in press) following the coral sand substrate used in AQUACOP (1977). However, preliminary data comparing survival of ablated broodstock on white coral and black gravel suggest that the latter may be better in terms of a greatly reduced mortality. A second run has just been started.

(6) *Light:* Pond stock *P. monodon* kept in maturation tanks under the following treatments: (a) blue light (435 mu), (b) red light (640 mu), (c) natural light, and (d) natural light plus unilateral ablation, produced fully mature ovaries and spawning only from the ablated females (Alava, 1979). Unablated prawns under blue and natural light developed Stage III ovaries, while those exposed to red light reached only Stage II ovaries (ovarian stages based on histological criteria rather than dorsal outline of ovaries). There is a need to repeat this experiment using ablated wild stock in the light of findings that normal harvest age *P. monodon* may not be ready for induced maturation.

At present, the broodstock tanks are covered with a black cloth which reduces light intensity by 40 to 60%.

(7) *Tank size and construction:* Our standard maturation tanks are made of ferrocement (Tolosa, 1978) because of available materials and cheap local labour rather than expensive and rare materials such as the fibre-glass sheets used in AQUACOP (1977). They are circular, 4 m wide and 1 m deep with a total capacity of 12 cu m. We plan to test different areas and depths to determine the minimum dimensions necessary for a *P. monodon* maturation tank.

Never-the-less, information about the mating behaviour of *P. monodon* provides some guidelines and also explains our past failures

TABLE 3. *Comparison of postlarval survival of spawnings from ablated pond stock* Penaeus monodon *females of different ages at ablation*

Pond source	Age in months at ablation	No. of spawnings	% Hatching rate	% Postlarval Survival from N_5N_6	References
Leganes, Iloilo ..	15	7	47.1	41.6*	Santiago, 1977
Pontevedra, Capiz ..	5	2	98.3	0	Primavera, 1978
		2	81.2	0	
Leganes, Iloilo ..	12-24	29	56.4	22.9**	Primavera *et al.* 1978
Iloilo & Capiz ..	5	3	52.0	0	
Batan, Aklan & Pontevedra, Capiz	5-6	16	20.8		Primavera *et al.* (in press)

* P_5P_6. ** P_{15}.

TABLE 4. *Maturation, fecundity, and hatching rate of ablated wild stock* Penaeus monodon *at different sex ratios* (after Alava and Primavera, unpub.)

Male : Female ratio	0 : 1 (0 : 60)	1 : 1 (30 : 30)	1 : 2 (20 : 40)	1 : 4 (12 : 48)
% spawners [1]				
First [2] ..	19.65 (11)	69.7 (15)	19.6 (21)	51.4 (14)
Second [3] ..	0	35.0 (5)	48.1 (10)	34.2 (4)
Third [4] ..	0	20.0 (1)	30.0 (3)	0
Ave. no. eggs/spawning ..	300,400	244,900	264,600	212,300
Total no. eggs produced ..	3,304,000	5,142,000	8,996,000	3,821,000
Ave. % hatching rate ..	0	35.8	27.8	22.7

[1]Figures in parenthesis refer to number of females.

[2] $\frac{\text{Daily no. 1st spawnings}}{\text{Daily no. surviving females}} \times 100$

[3] $\frac{\text{Daily no. 2nd spawnings}}{\text{Daily no. tagged 1st spawners}} \times 100$

[4] $\frac{\text{Daily no. 3rd spawnings}}{\text{Daily no. tagged 2nd spawners}} \times 100$

TABLE 5. *Data on survival and reproduction of ablated pond stock* Penaeus monodon *under different feeding regimes* (after Primavera *et al.*, in press)

Treatment	Pellet-pellet	Mussel-mussel	Mussel-pellet	Squid-pellet
Survival (%)				
male ..	56	40	52	32
female ..	16	20	14	8
Total no of 1st & subsequent spawnings ..	7	16	16	12
Ave. no eggs/spawning ..	136,800	179,300	180,300	140,300
Ave. % hatching rate ..	20.4	9.3	20.8	18.3
Total no. eggs produced ..	957,400	2,868,400	2,884,520	1,683,800
Total no. nauplii produced ..	195,200	266,200	598,760	308,440

using small glass aquaria and 1.5 ton fibreglass tanks (Primavera, 1979 a). Moreover, we have tested marine plywood tanks which turned out in the long run to be more expensive than ferrocement tanks because they perenially leak.

(8) *Water management and aeration:* Our tanks are on a flowthrough basis with daily exchange of 2-4x total volume. Water is pumped through perforated pipes embedded in the coral substrate and drained through a central cylinder. Because of the power requirement to run the water pump for the flowthrough, we are developing a recirculating system with a biological-mechanical filter using an air-water lift to decrease energy costs.

Although the flowthrough operates on a 24 hour basis, aeration by means of airstones is provided at night in case of pump breakdown. An alternative to airstones is an air-water lift system for more efficient water circulation, particularly in larger tanks.

C. *comparison of tank and pen systems:* Table 6 shows the construction and other requirements for land-based tanks and marine pens for prawn broodstock. Although no direct comparisons can be made, it appears that maturation, fecundity, and hatching rates are similar for ablated *P. monodon* held in both tanks and pens. However, there is reason to believe that mortality is higher in the pens because of greater stress on the broodstock while lifting the net and handling during the weekly samplings as well as disease related to pollution of the pen bottom by excess feeds (Primavera and Yap, 1979).

In contrast, broodstock in tanks are examined for ovarian maturation by means of an underwater light — there is no unnecessary handling of the prawns (Primavera, 1979 b). Good

TABLE 6. *Comparison of construction, stocking and other requirements of tanks and pen systems for prawn broodstock at the SEAFDEC Aquaculture Department* (after Primavera, 1979 b)

	Land-based tank (Tigbauan Station)	Offshore pen (Batan Station)
Dimensions and shape	4 m × 1 m ; circular	16 m × 16 m × 6 m ; rectangular
Volume	12 cu m	500-1,500 cu m
Total stock	50-60 at 1 male : 2 females	300 at 1 male : 2 females
Stocking density	4-7/sq. m	1/sq. m
Site requirements	power for 24 hr flow-through	protected cove ; absence of pollution
Unit cost (materials)	5,000 (ferrocement)*	10,000 (bamboo & mono-filament nylon)** ; including guardhouse
Longevity	minimal depreciation	2 years ; repairs after one year
Examination for gravid females	at night with under-water light ; 2x/week	net lifted during day ; weekly on 1st or last day of lunar phase
Manpower requirements :		
maintenance	1	1-2
sampling	1-2	3-4 divers + 1 sampler

* January 1978 estimates ; marine plywood, fibreglass sheets and canvas are substitutes.

** February 1979 estimates ; more durable but expensive materials may be used.

water quality is maintained in the tanks through daily removal of excess feeds. Moreover, a major disadvantage of bamboo pens is the relatively fast depreciation — after one year, the pen has to undergo repairs and after two to three years, it has to be replaced. Present engineering studies focus on the development and testing of pen prototypes that are more durable and easily transferable.

Other Penaeids

Screening of other penaeids for stocking in ponds during the ' off season ' of sugpo as well as for polyculture with *Chanos chanos* and other finfish started in mid 1978. Among the species we have tested are *P. semisulcatus*, *P. merguiensis*, *P. japonicus* and *Metapenaeus ensis*. Mainly because of the availability of experimental animals, we have successfully matured white prawn *P. indicus*. Already, we are rearing the F_3 generation in our hatchery tanks since we first ablated wild females in March 1979.

Table 7 shows fecundity and hatching rate of *P. indicus* matured in broodstock tanks. Maturation tanks are more suitable than pens for *P. indicus* and other species that are small and cannot withstand too much handling.

Table 7. *Fecundity and hatching rate of ablated and unablated* Penaeus indicus *matured in broodstock tanks*

	Wild stock	Pond stock
Ave. no. eggs/spawning		
ablated	43,330 (151)*	23,480 (744)
unablated	40,230 (130)	26,990 (74)
Ave. % hatching rate		
ablated	40.7 (151)	37.8 (744)
unablated	42.6 (130)	53.9 (74)

* Figures in parenthesis refer to no. of spawnings.

Conclusion

The five years of research in prawn maturation at the SEAFDEC Aquaculture Department have been very rewarding in the sense that at present, all penaeid fry reared in the Tigbauan hatchery tanks come from females matured in captivity. The remaining problems clearly define the objectives for the coming years which pertain to (1) improving the reproductive performance of ablated pond stock *P. monodon* ; (2) inducing maturation in captivity of other penaeids suitable for pond culture ; and (3) scaling down broodstock technology by decreasing tank and pen construction costs for extension to the small hatchery operator and others in the private sector.

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INDUCED SPAWNING IN *PARAPENAEOPSIS STYLIFERA* (H. MILNE EDWARDS) USING A STEROID HORMONE, 17-HYDROXY-PROGESTERONE

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ABSTRACT

For the current investigation, female prawns *Parapenaeopsis stylifera* were used. The mature female prawns having full grown ovaries were selected and divided into two groups (A and B), each containing 10 prawns and maintained them at low temperature (20°C) for 48 hrs, as compared to laboratory temperature (24-25°C), before use. A single dose of 17 Hydroxy-progesterone (50 μl/prawn = 50 μg/prawn), prepared in 100% Acetone : 6% NaCl (1 : 9) solution, was injected into the prawns of group A, whereas control prawns of group B received the same quantity of Acetone : NaCl solution. It was found that within 12 hrs, the prawns of group A were spawned whereas control prawns of group B were carrying the mature ovary. The results thus indicate that the steroid hormone, 17 Hydroxy-progesterone, is useful to induce spawning in this penaeid prawn at lower temperature, at which the prawn naturally does not spawn.

INTRODUCTION

THE IMMENSE food value of marine prawns has attracted the attention of scientists all over the world for extensive and intensive culture of selected prawn species. Hatchery for rearing prawns from egg through postlarvae stands to be a very important operation in the process of culture (Mack and Murphy, 1970 ; Alikunhi, 1978). Among the environmental parameters temperature seems to have profound influence on the breeding of marine animals (Crisp, 1957). Rao (1973) indicated that intensive spawning of penaeid prawns is related to rise in water temperature. Thomas *et al.* (1974) succeeded in spawning *Parapenaeopsis stylifera* at comparatively higher temperature (30°C). However, a very scant attention, has been paid towards means of artificial spawning in penaeid prawns. 17 α-hydroxy 20 β-dihydroprogesterone has been found promising in ovulating the lower vertebrates like carps at lower temperature (Jalbert *et al.*, 1977). There are some reports in literature on steroid metabolism in decapod crustaceans (Teshima and Kanazawa, 1971, 1973 ; Brminski and Klek, 1976). Therefore, we thought it apt to see the effect of a cheaply available steroid preparation 17 hydroxy-progesterone on the spawning of a commercially important penaeid prawn, *P. stylifera* at lower temperatures, generally at which they do not spawn.

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MATERIALS AND METHODS

The adult intermoult and mature female *P. stylifera* were purchased from local fishermen of Versova, Bombay and were brought immediately to the laboratory of the Central Institute of Fisheries Education, Bombay. Only spent animals in the size group 70-76 mm were selected and maintained in the laboratory in glass aquaria containing constantly aerated sea water (salinity 34 ± 1‰) at 24°C and under normal day night illumination. Prawns were fed on chopped *Acetes indicus* and water was changed partially every day and completely after every week to avoid it from fouling. Only those prawns having well developed ovaries in captivity were used for the experimentation. Method to assess maturity stages was followed as given by Rao (1968).

Injection material

17 hydroxy-progesterone was supplied by Biogen Chemicals, Bombay. 10 mg of the hormone was dissolved in 1 ml of 10% cold acetone of 15°C. Resulting 1 ml solution was diluted with 6% NaCl to 10 ml. Final concentration of the material used for injection was 1 μl = 1 μg (hormone).

Experiment

20 mature female *P. stylifera* were divided in two groups *viz*. A and B, each containing equal number of prawns held in four aquaria at 20°C. Group A served as experimental whereas group B was the control. All ten prawns from group A were injected with 50 μl (50 μg) of the hormone and treated prawns were transferred back to the respective aquaria. Similarly the prawns from group B were injected only with the mixture of Acetone : NaCl (1 : 9). Injections were given in the abdominal musculature between 1st and 2nd abdominal segments.

Observations and Results

Immediately after injection prawns were found to be inactive for first 30 sec and soon after they resumed their normal movements. No allergic or abnormal effect was noticed in the behaviour due to the hormone injection even after an hour's observation and prawns looked normal.

The prawns were kept under constant observation after the injections. 5 hrs after the start of the experiment, the prawns injected with hormone started spawning as evidenced from the foam like water bubbles at the surface of water in experimental aquaria. There was no change in the control aquaria.

After 12 hrs, water in each aquarium was sampled to note the larval development. Following stages were encountered only in the experimental aquaria (i) Eggs in various stages of cell proliferation, (ii) Nauplii inside the egg membrane and (iii) hatched nauplii (free swiming). Group A animals showed no presence of ovarian tissue except one, which showed a reduction in the size of ovaries. Probably it might be due to the partial spawning. Group B prawns did not spawn at all and they were bearing mature ovaries.

Discussion

The results of the current work have opened a new possibility of inducing spawning by 17 hydroxy-progesterone in marine prawn *P. stylifera*. It has been reported that a steroid hormone progesterone brings about the ovarian maturation in a marine prawn *P. hardwickii* (Kulkarni *et al*., 1979). Bomirski and Klek (1976) have shown that Human Chorionic Gonadotropin (HCG) stimulates oogonia in a sand shrimp *Crangon crongon*, to change rapidly in the meiotic oocytes. The possibility that 17 hydroxy-progesterone bringing about spawning in this prawn cannot be ignored as 17α-hydroxy 20β-dihydroprogesterone successfully induced spawning in carps at low temperature (Jalbert *et al*., 1977). In case of carps, it has been suggested that injection of 17α-hydroxy 20β-hydroprogesterone bypasses the synthesis of a steroid mediator at low temperature but is synthesised only when temperature is high and thus brings about successful spawning. Therefore it can be speculated that similar physiological mechanism might be occurring in this prawn. It is reported that steroid receptors are present in marine prawn *P. handwickii* and 17α-hydroxy 20β-dihydroprogesterone acts as steroid mediator in bringing about spawning in carps at high temperature. The need of exogenous supply of the steroid mediator at lower temperatures in both poikilotherms gains a good support. However, detailed studies are undergoing in our laboratory to draw the exact picture of the physiological mechanisms taking place after the injection of steroid and successive spawning.

The role of steroids in the reproductive physiology of prawns should attract the attention of the scientists to establish this modern trend of artificial maturation and spawning. It may emerge as a more dependable technology over the currently known eyestalk ablation technique (Arnstein and Beard, 1975; Santiago, 1977; Halder, 1977).

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ENDOCRINE REGULATION OF REPRODUCTION IN THE MARINE FEMALE PRAWN *PARAPENAEOPSIS HARDWICKII* (MIERS) (CRUSTACEA, DECAPODA, PENAEIDAE)*

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ABSTRACT

Effects of bilateral eyestalk extirpation and injections of eyestalk (ES) brain (Br) and thoracic ganglia (ThG) extract on the ovarian development of eyestalkless (Experiment-I) and normal (Experiment-II) *Parapenaeopsis hardwickii* have been investigated. Associated changes in the biochemical reserves of ovaries were estimated. The results of experiments showed that eyestalk ablation and injections of brain and thoracic ganglia extracts into both eyestalkless and normal *P. hardwickii* led to the acceleration of ovarian growth. Injection of eyestalk extract had suppressed the ovarian growth in both eyestalkless and normal *P. hardwickii*. Among the biochemical reserves, accumulation of glycogen and lipid was noticed in grown ovary with a concomitant decrease in protein quantity. Hence, it was inferred that the hormones produced in eyestalks have inhibitory and brain and thoracic ganglia have stimulatory influence on ovarian growth of *P. hardwickii*.

INTRODUCTION

As EARLY AS in the first half of the twentieth century Panouse (1943) in a shrimp, *Leander* Brown and Jones (1947, 1949), in a crayfish *Cambarus* and a fiddler crab, *Uca*, and Takewaki and Yamamoto (1950 a, b) in a shrimp *Paratya* have evidenced the occurrence of an ovary inhibiting hormone in the eyestalks of these crustaceans. This discovery has given a new direction to investigate the hormonal regulation of reproduction in female crustaceans. Later on, the above studies were extensively elaborated in several other crustaceans such as *Pandalus kessleri* (Aoto and Nishida, 1956), *Carcinus maenas* (Demeusy, 1965 a), *Scylla serrata* (Rangnekar and Deshmukh, 1968), *Barytelphusa cunicularis* (Nagabhushanam and Diwan, 1974), *Penaeus japonicus* (Laubier, 1975), *Penaeus orientalis* (Arnstein and Beard, 1975), *Homarus americanus* (Mauviot and Gastell, 1976) and *U. pugilator* (Webb, 1977) and suggested that in the decapod crustaceans the ovarian maturation and function appears to be regulated by inhibitory hormonal factor produced in the X-organ sinus gland complex in eyestalks. While investigating the role of central nervous system in reproduction of crustaceans, Otsu (1960, 1964) found that the repeated implantation or injection of thoracic ganglia into the sexually inactive female crab *Potamon dehaani* resulted in considerable ovarian growth. Gomez (1965) and Gomez and Nayar (1965) have also reported that besides the thoracic ganglia, the brain also secretes an ovarian growth accelerating hormone in the crab *Paratelphusa hydrodromous*. Perryman (1969) has demonstrated three endocrine factors influencing the ovarian growth in malacostracans ; two from the eyestalks and one from the supraoesophageal ganglion and stated that these factors, in common with several other crustacean hormones, are probably neurosecre-

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tory. Recently Herbaut (1975) has indicated in *Lithobius forficatus* that the pars intercerebralis hormones activate the growth of oocytes whereas Demassieux and Balesdent (1977) have observed the cyclic variation in function of β type neurosecretory cells of cerebral and nervous cord ganglia of an isopod *Asellus aquaticus*, in relation to reproduction. Foregoing literature obviously reveals that very fragmentary information is contributed in this regard for marine penaeid prawns, hence the present study is designed to decipher the role of hormones, produced in different neuroendocrine centres in oogenesis of a commercially valuable Indian marine prawn *Parapenaeopsis hardwickii*.

Material and Methods

About 130 adult and intermolt female prawns *P. hardwickii* were obtained from the coastal water of Versova, Bombay. They were held in the laboratory under normal day/night illumination in 30 × 50 cm glass aquaria (10 prawns per aquarium) containing continuously aerated sea water (salinity 33-35‰) at 23-25°C prior and during the experiments. Water was partially changed on every alternate days. The prawns were not fed during the period of the experiments which were run for twenty days, in two sets. Very less mortality was observed during the study.

Experiment-I

Seventy prawns of equal size were selected and divided into seven groups each containing ten prawns. This set of experiment consists of normal eyestalk intact controls (Group I); 20 days eyestalk extirpated and stubs cauterized (Group II), eyestalkless prawns receiving injections of crustacean saline (Pantin, 1934) (Group III), boiled eyestalk (Group IV), unboiled eyestalk (Group V), brain (Group VI) and thoracic ganglia (Group VII) extracts separately on 7th and 14th day of eyestalk ablation counting from the day 0 of the extirpation. 50 μl/prawn of crustacean saline and the extracts of eyestalks (2 ES), brain (1Br) and thoracic ganglia (1 ThG) were injected separately for every time.

Experiment-II

Fifty prawns of equal size were selected and divided into five groups, each consisting 10 prawns. This set contains the normal (eyed) controls (Group A), normal injected with crustacean saline (Group B), unboiled eyestalk (Group C), brain (Group D) and thoracic ganglia (Group E) extracts on 7th and 14th day separately. Quantity and concentration of the saline and extracts of different neuroendocrine centres injected were the same as used in the first set.

Methods of eyestalk ablation, preparation and injection of ES, Br and ThG extracts and maintenance of the post-treated prawns were the same as described by Nagabhushanam and Kulkarni (1978). Ovarian index (OI), histological preparation and scrutinization of the ovary and biochemical estimations were done by the procedure of Kulkarni *et al.* (1979). Significancy of the obtained data was statistically analysed by applying student 't' test.

Results

Experiment-I: Effects of eyestalk ablation and injections of eyestalk, brain and thoracic ganglia extracts on the ovarian growth of eyestalkless P. hardwickii.

Data given in Table 1 clearly show that there was a significant ($P < 0.01$) increase in the OI and the oocyte diameters of the prawns in Groups II, VI and VII when compared with the control prawns of Group I whereas OI and oocyte diameter declined significantly ($P < 0.01$) in the prawns of Group V as compared to the prawns of Group II and did not differ significantly ($P > 0.05$) from Group I. Among the biochemical reserves, total glycogen and lipid quantity increased and protein content

TABLE 1. *Effect of eyestalk ablation and injections of eyestalk and CNS extract in eyestalkless prawns, on the development and associated biochemical contents of ovary in female* P. hardwickii

Treatments	No. of Prawns	Average wt. of ovaries (gms) ± S.D.	Average oocyte diameter (μ) ± S.D.	Ovarian Index (OI) ± S.D.	% Protein ± S.D.	% Glycogen ± S.D.	% Lipids ± S.D.
Normal (control) (Group I) ..	18	0.500 ± 0.040	80.65 ± 2.25	1.5 ± 0.42	5.676 ± 1.13	16.634 ± 1.27	1.661 ± 0.14
Eyestalk ablated cauterized (Group II) ..	20	4.560 ± 0.410	136.85 ± 4.15	6.4 ± 0.66	3.121 ± 0.78	21.864 ± 2.04	3.941 ± 0.26
Eyestalkless + 50 μl/P Physiological saline .. (Group III)	18	4.300 ± 0.700	134.65 ± 4.25	5.9 ± 0.81	3.461 ± 0.84	21.514 ± 1.69	3.634 ± 1.11
Eyestalkless + 50 μl/P (= 2 ES/P) boiled ES extract (Group IV) ..	20	4.200 ± 0.350	133.15 ± 3.45	6.0 ± 0.50	3.341 ± 0.66	21.381 ± 1.32	3.448 ± 1.16
Eyestalkless + 50 μl/P (= 2 ES/P) unboiled ES extract (Group V) ..	20	1.800 ± 0.110	90.75 ± 3.05	2.9 ± 0.32	4.932 ± 0.37	17.036 ± 1.87	2.016 ± 0.79
Eyestalkless + 50 μl/P (= 1 Br/P) of Brain extract (Group VI) ..	21	6.290 ± 0.220	152.28 ± 2.32	7.0 ± 0.30	2.634 ± 0.37	23.984 ± 1.32	4.021 ± 1.03
Eyestalkless + 50 μl/P (= 1 ThG/P) of ThG extract (Group VII) ..	20	5.985 ± 0.185	148.31 ± 2.44	6.8 ± 0.22	2.741 ± 0.26	23.67 ± 1.43	3.996 ± 1.11

decreased significantly ($P < 0.05$) in ovaries of the prawns in Groups II, VI and VII as compared to the values of the prawns in Group I but a significant ($P < 0.05$) decrease in total glycogon and lipid was observed in the ovaries of the prawns in Group V when compared with the values of the prawns in Group II and were insignificantly ($P > 0.05$) variable from the values of Group I.

Experiment-II : Effect of eyestalk, brain and thoracic ganglia extract injections on the ovarian growth of the normal P. hardwickii.

Data presented in Table 2 clearly indicate a significant ($P < 0.01$) increase in OI and oocyte diameter in the prawns of Groups D and E whereas a considerable decrease in OI and oocyte diameter was noticed in the prawns of Group C when compared with the values of Group A. Total glycogen and lipid concentrations augmented and protein quantity declined significantly ($P < 0.05$) in the ovaries of prawns in Groups D and E as compared to the Group A, but a slight decrease in glycogen and lipid content and increase in protein concentration was observed in the ovaries of the prawns in Group C which were not significantly ($P > 0.05$) different from Group A.

Discussion

As early as in 1955, Benett and Giese for the first time, had described the gonad index as a function of reproductive activity of marine invertebrates. It is quite clear from the data obtained in our current study that there was an increase in the OI of the eyestalkless prawns accompanied by augmentation in the average ovarian weight and oocyte diameter. Histological observations of the ovaries indicate that ovarian growth is coupled by a rapid onset of vitellogenesis. In the normal control prawns the oocytes were compact and adhered to each other having homogenous ground cytoplasm, but oocytes of growing ovaries were differentiated and larger in size and cytoplasm has become quite dense and granular, indicative of vitellogenin synthesis. The inhibition of the ovarian growth and vitellogenesis was found in the eyestalkless prawns administered with the unboiled eyestalk extracts. Results similar to those reported here were also obtained by Rangnekar and Deshmukh (1968) in *S. serrata*, Bomirski and Klek (1974) in *Crangon crangon*, Nagabhushanam and Diwan (1974) in *B. cunicularis*, Charniaux-Cotton (1975) in *Orchestia gammarellus* and *Lysmata seticaudata* and Webb (1977) in *U. pugilator* who reported that well known inhibitory hormone released from the eyestalks regulates the ovarian growth and vitellogenesis and ablation of which is resulted in acceleration of ovarian development and vitellogenesis. The suppression of the ovarian growth in eyestalkless prawns by eyestalk extract injection is not complete because the values of their OI and oocyte diameter are relatively greater than those of the normal control prawns. The reason for this incomplete inhibition may be speculated as due to time that is passed between ablation of the eyestalks and the injections of the eyestalk extract, during which period the blood titer of the inhibitor slashed to such a point that a gonadal growth accelerating factor was allowed to liberate from elsewhere in the body. These our findings agree well with the similar observations recorded for crabs and crayfishes by earlier researchers (Brown and Jones, 1949 ; Rangnekar and Deshmukh, 1968 ; Nagabhushanam and Diwan, 1974). Boiled eyestalk extract did not show any effect on the ovarian growth of eyestalkless prawns, indicating the proteinaceous nature of eyestalk hormone which is destroyed after heating as reported in several other crustaceans (Fingerman, 1974). Hence, the results of our study suggest that eyestalks of *P. hardwickii* secrete an ovarian growth inhibiting or vitellogenesis suppressing principle which is proteinaceous in nature. During the complete period of our experiments, no moulting was observed

TABLE 2. *Effect of eyestalk and CNS extract injections on the development and associated biochemical constituents of ovary in normal female* P. hardwickii

Treatments	No. of prawns	Average wt. of ovaries (gms) ± S.D.	Average oocyte diameter (μ) ± S.D.	Ovarian Index (OI) ± S.D.	% Protein ± S.D.	% Glycogen ± S.D.	% Lipids ± S.D.
Normal (control) (Group A) ..	15	0.600 ± 0.05	76.85 ± 1.15	2.1 ± 0.31	6.105 ± 1.05	18.735 ± 1.37	1.945 ± 0.11
Normal + 50 μl/P Physiological saline (Group B) ..	15	0.640 ± 0.08	78.15 ± 2.85	2.3 ± 0.22	6.088 ± 1.12	18.334 ± 1.22	1.810 ± 0.24
Normal + 50 μl/P (= 2 ES/P) eyestalk extracts (Group C) ..	16	0.505 ± 0.06	65.45 ± 3.15	1.54 ± 0.16	6.904 ± 1.25	16.860 ± 1.24	1.245 ± 0.11
Normal + 50 μl/P (= 1 Br/P of Brain extract (Group D) ..	18	4.650 ± 0.20	125.65 ± 3.35	6.1 ± 0.41	3.245 ± 0.81	23.648 ± 2.01	3.991 ± 0.53
Normal + 50 μl/P (= 1 ThG/P) of ThG extract (Group E) ..	18	4.860 ± 0.31	119.85 ± 3.15	5.7 ± 0.52	3.186 ± 0.42	22.775 ± 1.93	3.938 ± 1.11

in the eyestalkless *P. hardwickii*. It is demonstrated earlier that in a large number of crustaceans removal of eyestalks leads to the acceleration of moulting and not to gonadal development, because moult inhibiting principle resides in eyestalks. Bauchau (1961); Demeusy (1965 a, b) and Bliss (1966) have reported in the brachyurans that an antagonism exists between the process leading to the somatic growth as indicated by moulting in juvenile crabs and those leading to the gonadal growth in mature ones. Therefore, when eyestalks are removed, whatever the set of physiological process is dominant at the moment becomes visible. Hence, we can infer that eyestalk ablation in *P. hardwickii* induce ovarian growth and not moulting, although an antagonism may be expected to exist between the process leading to moulting and gonadal growth, the latter was found to dominate in this prawn.

For brachyurans it was reported previously that the ovarian growth is regulated by two antagonistic factors, one stimulating and other inhibiting, produced and liberated in different neuroendocrine centres of the same individual (Otsu and Hanaoka, 1951). In the present study we found that the brain and thoracic ganglia extracts when injected into the eyestalkless as well as normal *P. hardwickii*, there was a rapid growth of ovary indicating significantly enhanced OI, oocyte diameter and average ovarian weight. Therefore, it is inferred that brain and thoracic ganglia produces a factor which accelerates the ovarian growth in this prawn. Our observations resemble well with the earlier reports of Gomez (1965), Gomez and Nayar (1965) and Nagabhushanam and Diwan (1974) who have evidenced the presence of an ovary stimulating principle in the brain of the crabs. Herbaut (1975) has reported in a myriapod crustacean *L. forficatus* that the hormone of pars intercerebralis accelerates the growth of oocytes. Otsu (1960, 1964) has observed that thoracic ganglia of the crab *P. dehaani* possess a factor which stimulates the ovarian growth. Matsumoto (1958) found in the *Eriocheir* that the secretory activities of some of the neurosecretory cells in the thoracic ganglia correspond fairly well with the seasonal ovarian development. Recently, Demassieux and Balesdent (1977) have observed a cyclic change in the β type neurosecretory cells of cerebral and nervous cord ganglia of an isopod *A. aquaticus* in relation to reproduction.

The important biochemical reserves of many crustaceans are glygogen and lipid (O'conner and Gilbert, 1968; Hoank and Scheer, 1970), which are accumulated in the ovaries and depleted from the midgut gland during the oogenesis, because these organic materials are transferred from the midgut gland to the maturing ovaries. Particularly glycogen serves as a reserve food and utilized for the formation of ovarian products. In this study we found that during the ovarian development of the prawns in both the experimental sets (Groups II, VI, VII and D and E) there was a significant increase in the glycogen and lipid quantities of the ovaries. Hence, it can be surmised that these accumulated organic constituents must be channelled from the midgut gland which serves as a food reservoir, which is to be used for the formation of viable reproductive elements, as evidenced earlier (Kulkarni *et al.*, 1979). Our prediction was strengthened by the similar observations of Jyoti (1974) in *Caridina weberi*, and Diwan and Nagabhushanam (1974) in *B. cunicularis*. In a crayfish *Orconectes nais* (Rice and Armitage, 1974) it had been shown that the lipid mobilizes from the midgut gland to the ovary as it matures which is coupled with a marked increase of lipid content in ovaries. Thus, in *P. hardwickii*, the midgut gland reserves were shifted to the ovaries during its maturation in which the glycogen and lipid quantities were increased accompanied by decrease in protein content showing the conversion of protein into other organic substances to meet energy requisition during ovarian maturation. Similar observations were recorded by Martin (1973) in *Carcinus maenas* and Zerbib (1977) in *O. gammarellus* indicating the protein absorption during oogenesis. Thus, the ovarian growth is reflected by changes in the energy reserves of the midgut gland and ovaries of *P. hardwickii* (Kulkarni and Nagabhushanam, 1979). Consequently, the biochemical changes of midgut gland and ovaries are of unique importance for deciphering energetics of reproduction as they show the pattern as to how the gonads are converting organic reserves into the reproductive activities.

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SURVIVAL, MATURATION, FECUNDITY AND HATCHING RATES OF UNABLATED AND ABLATED *PENAEUS INDICUS* H. M. EDWARDS FROM BRACKISHWATER PONDS*

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ABSTRACT

Penaeus indicus H. M. Edwards harvested after three months of rearing in brackishwater ponds and averaging 6.9 g for females and 5.6 g for males were stocked in two 12 cu m flowthrough ferrocement tanks at 240 females and 200 males per tank. The females were ablated on one eyestalk in one tank and remained unablated in the other tank ; all males were unablated. Ablated females spawned up to 7 times per female; unablated females spawned up to only 3 times during the two month duration of the experiment. Ablated females produced a total number of 17.5×10^6 eggs, 6.6×10^6 nauplii, and an average of 23,480 eggs/spawning and 37.8 % hatching rate from a total of 757 spawnings. Unablated females produced a total of 2.0×10^6 eggs, 1.1×10^6 nauplii, and an average of 26,990 eggs/spawning and 53.9% hatching rate from a total of 74 spawnings. Survival of ablated females was 53.5% compared to 69.4% for unablated females ; males in both tanks averaged more than 90% survival.

INTRODUCTION

AFTER four years of experience with the sugpo *Penaeus monodon* at the SEAFDEC Aquaculture Department, it became apparent that, at least in Iloilo province, the dry months of December to March constitute an 'off season' for the species in terms of water temperature in hatchery tanks which is too cold for larval rearing and pond salinity which is too high for culture (Yap *et al*., 1979).

Moreover, there is a need to provide the seed of other prawn species for polyculture in brackishwater ponds with *P. monodon* or with finfish such as the milkfish *Chanos chanos*. Interestingly, local cuisine favours the use of smaller sized shrimp instead of the large sugpo in the preparation of *kinilaw* and other native recipes.

Toward this end, screening studies started in 1978 have included half a dozen species. So far, *Penaeus indicus*, locally known as *Putian* or *Hipong puti* (meaning white shrimp in reference to its light colour) is the most promising in terms of maturation. Preliminary observations show that *P. indicus* matures in captivity with or without ablation (Primavera and Yap, 1979) and that both larval rearing and pond culture are relatively easy.

The objective of this experiment is to compare the effect of unilateral eyestalk ablation, a method associated with *P. monodon* culture (Primavera *et al*., 1978), on maturation and survival in *P. indicus* for purposes of standardizing broodstock techniques for the species.

MATERIALS AND METHODS

P. indicus were harvested from brackishwater earthern ponds after three months of

* Contribution No. 59 of the SEAFDEC Aquaculture Department.

rearing from hatchery-reared postlarvae (P_7P_8) and stocked in two maturation tanks. Average body weight was 6.9 g for females and 5.6 g for males.

The circular ferrocement maturation tanks are 4 m wide and 1 m deep with a total water volume of 12 cu m. Sand-filtered seawater is pumped through perforated poly-vinyl chloride pipes located in the coralline substrate and drained through a central cylinder. The 24 hour water flow through accounts for a daily exchange of 2-4x total water volume. Airstones are provided in case the water pump breaks down. A dark cloth cover reduces light intensity inside the tanks.

After one week of acclimation, the females in one tank were ablated by pinching either the left or right eyestalk of the prawn between the thumb and forefinger and squeezing the eye contents outwards. The females in the second tank and the males in both tanks remained unablated. Upon examination, males were found to have well-developed spermatophores.

The animals were daily fed shelled frozen mussel *Modiolus metcalfei* in the morning and commercial pellets in the afternoon at a combined 3% of total biomass. Excess food was siphoned out every morning and feeding rate adjusted according to daily consumption.

Regular sampling of the broodstock (n=20) for measurements of body weight (B.W), carapace length (C.L=base of eye notch to end of carapace) and body length (B.L=base of eye notch to tip of telson) was undertaken.

The maturation tanks were examined for mature females every 2-3 days. Females with fully mature ovaries, visible as greenish masses through the transparent dorsal exoskeleton, were scooped out and placed in 300 litre conical fiberglass spawning tanks at 5-20 females per tank. The animals rested on a black nylon net, placed above the tank bottom to prevent the spawners from eating eggs that may settle on the bottom. (*P. indicus* spawners placed in glass aquaria had been earlier observed to eat their eggs).

Once a female had spawned, it was tagged on the unablated eyestalk with a 2 x 15 mm brass tag. With each subsequent spawning, the old tag was replaced with a new one bearing the appropriate number code for the spawning.

Egg counts were obtained by stirring the water to achieve a uniform suspension of the eggs, taking three one-litre aliquot samples, counting the number of eggs in each sample and multiplying the average by the total water volume of the spawning tank. Nauplii counts were obtained in a similar manner and hatching rates for eggs from a number of spawners in a single tank computed accordingly.

The ranges of physico-chemical parameters, monitored at 9.00 a.m. three times a week were (*a*) temperature: 26.0-31.8°C; (*b*) salinity: 26.4-31.9 ppt; (*c*) pH: 7.3-8.1; (*d*) alkalinity: 115-186 ppm and (*e*) NO_3-N: 0-0.205 ppm. Low salinities of 15-16 ppt were recorded during a typhoon in late September. Dissolved oxygen measured at the start and end of the experiment ranged from 5.3 to 5.8 ppm.

The study was started on July 25, 1979 and terminated on October 1, 1979 after 68 days.

Results and Discussion

The z-test showed a significantly higher survival at 69% for unablated females compared to 53% for ablated *P. indicus* after two months (Table 1). The higher mortality rates for the ablated group could be due to the added stresses of ablation and spawning (upto a maximum 7 spawnings for one female). Males in both groups had a higher survival for over 90% (Table 1) compared to both unablated and ablated females. This can be traced to lack of handling and spawning stress, as observed elsewhere for *P. monodon* broodstock (Primavera *et al.*, 1978).

In terms of growth, males in both groups showed similar trends (Fig. 1). Unablated females tended to be bigger although the t-test showed no significant difference in body length and weight between ablated and unablated females. However, bilaterally ablated *P. monodon* reached twice the body weight of unablated controls after 1.5 months in rearing ponds (Alikunhi *et al.*, 1975).

for ablated *P. indicus* and 26,990 eggs/spawning for unablated females (Table 1). However, average hatching rate of 53.9% was significantly higher for unablated females compared to 37.8% for ablated spawners. With ablated females spawning upto 7 times, the period between successive spawnings (as short as three days) was probably inadequate for complete ovarian development. This could result in poorer egg quality and a lower hatching rate. In contrast, Rao (1968) stated that in nature, the interval between spawnings from a *P. indicus* female is two months.

TABLE 1. *Growth and survival of unablated and ablated* Penaeus indicus *in maturation tanks*

	Unablated		Ablated	
	Male	Female	Male	Female
No. stocked	200	242	200	245
No. survivors	186	168	184	131
% survival*	93.0	69.4	92.0	53.5
Ave. C. L. (mm)				
Initial	18	20	18	20
Final	21	24	21	24
Ave. B. L. (mm)				
Initial	73	78	73	78
Final	85	94	86	91
Ave. B. W. (g)				
Initial	5.6	6.9	5.6	6.9
Final	9.7	13.2	9.4	12.0

* z-test showed significant difference between unablated and ablated females at 5% level.

Ablation had a positive effect on maturation in terms of a greater number of spawnings per female and a consequent ten fold increase in total number of spawnings, an eightfold increase in total number of eggs and a sixfold increase in total number of nauplii produced. Ablated females produced a total number of 757 spawnings, 17.5×10^6 eggs, and 6.6×10^6 nauplii compared to a total of 74 spawnings, 2.0×10^6 eggs, and 1.1×10^6 nauplii from unablated females (Table 2).

The z-test showed no significant difference in average fecundity of 23,480 eggs/spawning

More than 90% of the ablated females had the first spawning within three weeks after ablation (Fig. 2). Rematurations constitute a greater proportion of later spawnings. It is remarkable that practically 100% of ablated females had at least one spawning compared to less than 25% for unablated ones (Tables 3, 4, and Fig. 2). (The count of 308 ablated females with a first spawning in Table 4, 63 more than were initially ablated, can be explained by some spawnings occurring during the interval between samplings of the maturation tank and therefore going unrecorded). Within a comparable period, the total number of spawners obtained from *P. monodon* constitutes only around 30% of initial ablated population (Primavera *et al.*, 1978).

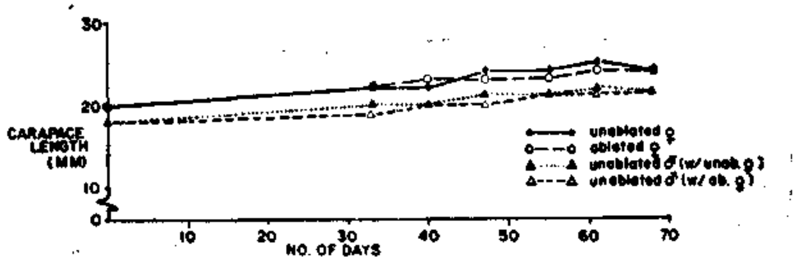

Fig. 1a. Carapace length of unablated and ablated Penaeus indicus in maturation tanks.

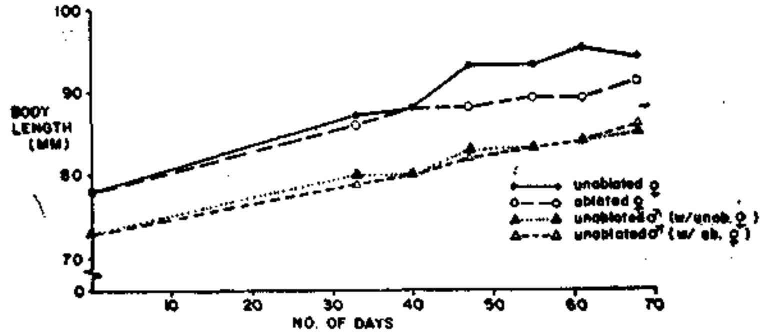

Fig. 1b. Body length of unablated and ablated Penaeus indicus in maturation tanks.

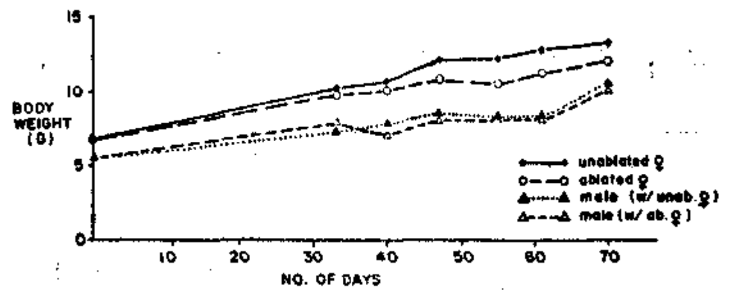

Fig. 1c. Body weight of ablated and unablated Penaeus indicus in maturation tanks.

Fecundity tends to increase with subsequent spawnings in both unablated and ablated females (Tables 3 and 4). This may be due to the increase in size of the females (Fig. 1). According to Rao (1968), a female of 140 mm total length can yield 68,000 eggs. The closest figure to this is a fecundity of 95,000 eggs for the third spawnings in the unablated group (Table 3). It may be that as unablated females become older and larger, the rate of maturation and number of spawnings will increase. A second run using older and larger *P. indicus* pond-stock should provide valuable information.

TABLE 2. *Maturation in unablated and ablated* Penaeus indicus *in maturation tanks*

	Unablated	Ablated
Total no. spawnings (first and subsequent spawnings)	74	757
Total no. eggs produced	1,997,000	17,473,000
Ave. no eggs/spawning	26,990	23,480
Total no. nauplii produced	1,076,000	6,599,000
Ave. % hatching rate*	53.9	37.8

* z-test showed significant difference between unablated and ablated females at 5% level.

TABLE 3. *Number of spawnings, fecundity and hatching rate in unablated* Penaeus indicus *in maturation tanks over a two-month period*

Spawnings	Total no. spawnings	Total no. eggs produced	Total no. nauplii produced	Ave. % H.R.	Ave. no. eggs/spawning
1st ..	57	1,320,000	747,000*	57.6	23,160
2nd ..	15	487,000	310,000	63.6	32,470
3rd ..	2	190,000	19,000	10.0	95,000
Total ..	74	1,997,000	1,076,000	53.8	26,990

* Nauplii from one spawning not counted.

TABLE 4. *Number of spawnings, fecundity and hatching rate in ablated* Penaeus indicus in *maturation tanks over a two-month period*

Spawning	Total no. spawnings	Total no. eggs/produced	Total no. nauplii produced	Ave. % H.R.	Ave. No. eggs/spawning
1st ..	308	5,871,000*	2,399,000	40.9	19,900
2nd ..	189	3,914,000	1,304,000	33.3	20,700
3rd ..	121	3,388,000	1,286,000	38.0	28,000
4th ..	77	2,042,000	753,000	36.9	26,520
5th ..	42	1,361,000	634,000	46.6	32,400
6th ..	17	805,000	216,000	26.8	47,350
7th ..	3	92,000	7,000	7.6	30,670
Total ..	757	17,473,000	6,599,000	37.8	23,480

* 13 spawners with no egg counts.

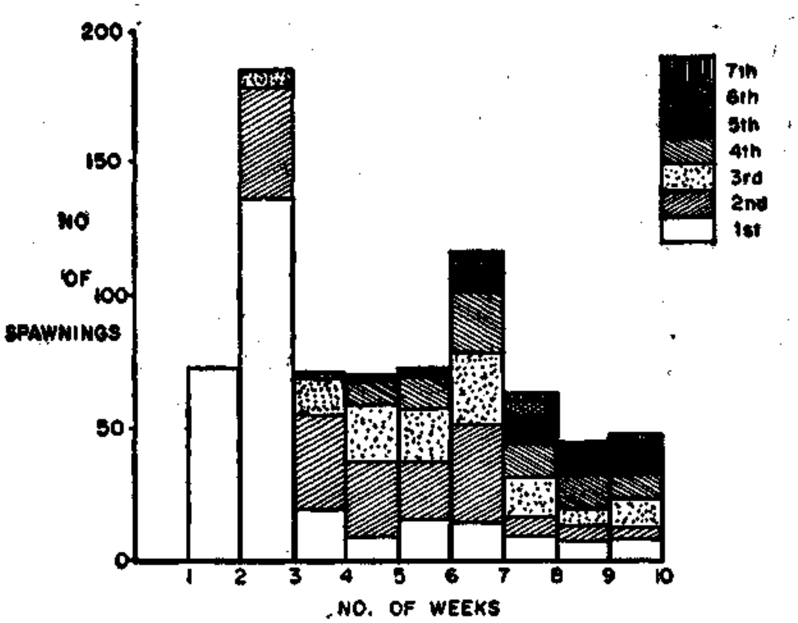

Fig. 2. Weekly number of first and subsequent spawnings of ablated pond stock *Penaeus indicus*.

Hatching rate is more or less the same except for the last spawnings in both unablated and ablated females (Tables 3 and 4). This could be related to both availability and viability of sperm in the thelycum of the female. If an ablated female undergoes another spawning as quickly as three days after the previous one for a total of 3-4 spawnings within one intermoult period, the quantity and quality of sperm may be greatly decreased after the first few spawnings. Only after the next moult could the female mate and get a fresh spermatophore deposition.

On at least one occasion, we could find no eggs in the spawning tank although the females had obviously spawned since the spent ovaries were visible through the dorsal exoskeleton. The only conclusion is that the females had reached the tank bottom by somehow penetrating the nylon material and eaten their eggs, an observation earlier made for *P. monodon* (AQUACOP, 1977).

Most of the nauplii were viable and were reared in hatchery tanks, forming the F_2 generation. The animals in this experiment came from F_1 postlarvae reared in the hatchery and stocked in the Leganes ponds in April 1979.

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REARED BROODSTOCK OF *PENAEUS MONODON*

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ABSTRACT

Since 1975, maturation and spawning in captivity of *Penaeus monodon* has been achieved in the 'Centre Océanologique du Pacifique', a CNEXO Centre in Tahiti. The five first animals have been imported from Fiji Islands and in May 1979, four generations have been obtained.

Under the rearing conditions followed at the Centre, reproduction is achieved all throughout the year. Maturation is induced by unilateral eyestalk ablation on pond reared animals maintained in tanks on adequate food.

Results concern mating behaviour, ovarian development, number of spawnings per female and egg viability. The rearing and the maintenance conditions of the captive broodstocks are particularly important to obtain reliable results necessary to sustain commercial hatcheries. Mass production of postlarvae is routinely achieved.

INTRODUCTION

A RELATIVELY stable environment in French Polynesia allows year round culture of penaeid shrimp. As no local shrimp of commercial interest lives in the surrounding waters, different foreign species were tested and the prerequisite was the possibility to obtain maturation and reproduction in captivity. Since 1973 the Centre Océanologique du Pacifique (COP) has achieved this goal on seven different species using unilateral eyestalk ablation to induce ovarian maturation. AQUACOP 1975, 1977a, 1977 b and successive generations have been obtained. For tropical conditions and specially high water temperatures 25°C-35°C *Penaeus monodon* is one of the best candidate (AQUACOP 1977 a). This paper deals with the results obtained so far at the COP in rearing broodstock and closing the cycle for that Indo-Pacific species which is particularly abundant in the Philippines, Taiwan and Indonesia where it is cultured mostly mixed with *Chanos chanos* (Ling, 1972).

MATERIALS AND METHODS

The COP is located in the Vairao lagoon where the water is largely renewed by the swell action above the barrier reef ; this provides a true oceanic water which gives a stable environment. The temperature fluctuates from 25°C in the winter to 29°C in the summer, the salinity is 35 ppt and pH remains constant at 8.2. The load in organic matter is always low.

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The first broodstock has been constituted from 14 juveniles and adults captured in the wild in Fiji and New Caledonia. All the other animals are born and reared in captivity through the new generations.

Different kind of ponds and tanks are used to grow the shrimps to the maturation size: earthen ponds from 700 to 2,500 m^2 and concrete tanks with compacted coral bottom from 700 to 1,200 m^2 where the daily renewal of the water varies around 10% of the total volume. The new constituted broodstocks are transferred in a 400 m^2 tank of 2 m water depth where the water is injected in the sand bottom through imbedded perforated plastic pipes.

The largest and healthiest animals selected by divers are stocked in 12 m^3 circular maturation tanks previously described (AQUACOP, 1975; 1977 b): the water depth is 80 cm, the substrate is coral sand and the water renewal is 2-3 times daily. The temperature varies from 24° to 19°C. 20 females from 50 to 150 g and 20 males from 40 to 60 g mean weight are placed in each tank. Compound pellets of 60% protein with a supplement of frozen squid flesh are distributed twice a day. Unilateral eyestalk ablation is practised on the females by simple pinching of the eyestalk and each is double tagged: ring of an elastic silicone tube bearing a label is inserted around the remaining eyestalk and an other label is glued on the carapace or inserted on the rostrum. When moulting the first tag stay on the animal as the other one is found on the discarded carapace.

This technique allows to follow each female individually in a tank. The females are examined every day at dawn for ovarian development without handling to avoid stresses: this is done under the beam of a water proof handlight as the dark carapace does not allow a direct viewing of the ovaries. The developing ones are removed in smaller tanks from 150 1 to 2 m^3 where a supplement of Troca flesh and fresh mussel is added. Eggs are collected by passing the water through a sieve of 100 μ. The spawning quality is determined by the percentage of normal, abnormal and unfecundated eggs. Larvae are reared using the Galveston technique in 500 1 or 2 m^3 tanks at density of 50 to 100 post-larvae/litre.

RESULTS

In the described rearing conditions and in selecting the biggest animals it takes about 9 to 12 months to constitute a new broodstock: 6 months to reach 30 g size and 3 to 6 months more to reach 50 to 120 g size when maturation occurs (Fig. 1). The first spawning was

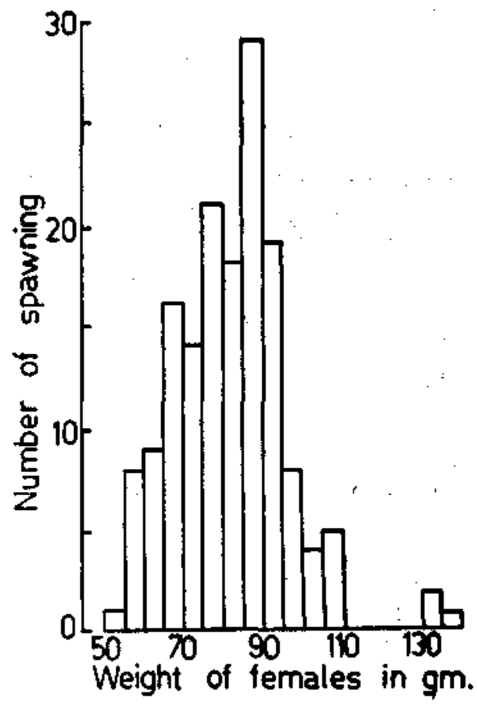

Fig. 1. Number of spawning in relation to weight of females.

obtained in November 1975 and in May 1979 F_4 generation was achieved.

In the maturation tanks adults *P. monodon* lie on the sand substrate and rarely burrow, their swimming activity is also low day and night. The moulting periodicity for epedunculated females is about 3 weeks. An extension of this period is an indication of too old or weak animals.

If the eyestalk epedunculation is done on healthy animals no mortality occurs except for freshly moulting females.

Above 25°C and for epedunculated animals maturation and spawning occur throughout the year although the ovarian development is minimal during the coldest period from July to September. The few spawnings of non-epedunculated females have been recorded in May and June. The observed courtship and mating behaviour takes place at dawn just after the moulting of the females when the shell is soft; it agrees with the detailed description of Primavera (1979). The success of the impregnation can be seen the next morning by a remaining whitish jelly hanging from the thelycum splits.

After ablation the minimum time for a female to develop full ovaries and to spawn is three days, maximum time is three to four weeks and in this case one moult happens before the maturation begins.

The duration of the ovarian development itself is also variable; for some animals it takes three to four days for others it can last two weeks (Table 1).

The colour of the developping gonad is first whitish then it turns greenish to be dark green on spawning day; there is some exceptions and the colour could be only whitish the spawning day. For some females it is quite easy to determine exactly the spawning day as their ovaries show a large swelling in the first abdominal segment, unfortunately females can also spawn when the ovaries are just developed without swelling. The texture is more significant and must be granulous but it is necessary to handle the animal with a subsequent stress.

Table 1 and 2 and Fig. 2 give the detailed results of some particular experiment in maturation tanks. It can be seen:

— the number of maturation and subsequent spawning is high during a two month period after that the number and the quality of spawning decreased heavily as the healthy state of the stock decreased (Table 2).

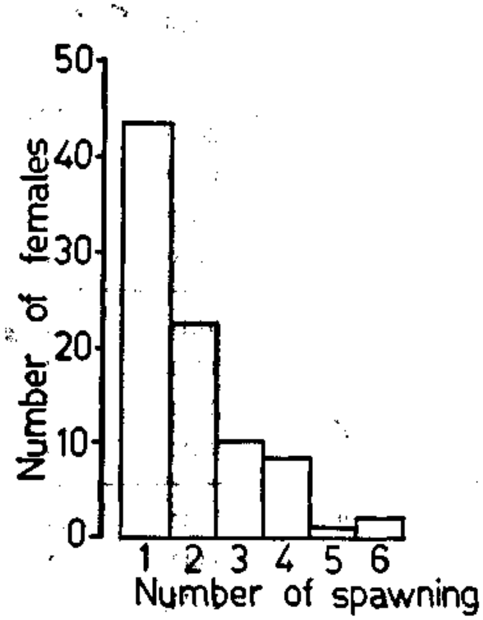

Fig. 2. Spawning frequency in *P. monodon.*

— each female can give several spawnings in a short period of time between two moults: after each spawning the gonad is completely empty but can start again to develop the next day (Table 1 and Fig. 2).

The same stock of sperm is used for the different spawnings and the number of fertilized eggs generally seems in relation with the quantity of sperm injected in the thelycum.

— regression of developing ovaries occurs. Stress during handling can be suspected but is also occurs with undisturbed females.

TABLE 1. *Individual experiments on females of* Penaeus monodon

No. ♀	Date	D.M.	N.ϖ	% Fec.	W ♀
14(1)	07.02	6	120,000	87	95
	18.02	—	Molt —	—	—
	23.03	4	240,000	0	95
	29.03	3	310,000	0	95
2(7)	13.09	6	250,000	70	68
	26.09	—	Molt —	—	—
	04.10	2	90,000	0	65
	07.10	2	100,000	0	65
	11.10	4	40,000	0	65
20(6)	08.11	3	150,000	25	65
	17.11	7	160,000	0	65
	22.11	—	Molt —	—	—
	06.12	6	90,000	0	70
9(12)	10.12	10	330,000	80	132
	13.12	2	540,000	90	135
	16.12	2	490,000	80	135
12(12)	22.10	3	150,000	80	—
	29.10	3	180,000	95	83
	02.11	2	180,000	85	85
	06.11	2	65,000	85	85
21(12)	24.11	16	310,000	95	102
	30.11	5	Regression	—	—
	04.12	—	Molt —	—	—
	13.12	3	60,000	50	105
	16.12	2	310,000	80	105
	19.12	2	290,000	58	105

N ϖ : Number of eggs ; D.M : Beginning of maturation (days) ; W ♀ ; Weight of females (grams) ;

TABLE 2. *Experiments on* P. monodon *in a maturation tank during* 1979

Month	Number ♀	Maturation	Regression	Spawning	No. eggs	$\overline{N}$ eggs/ ♀	%Fecundation ♀	%Fecundation ●	Weight g/♀
13.12 to 31.12	25	2	0	2	530,000	265,000	2	25	75
01.01 to 31.01	22	22	8	14	3,085,000	107,000	14	55	82
01.02 to 28.02	19	19	7	11	1,800,000	205,000	6	70	86
01.03 to 14.03			Complete Darkness						
15.03 to 31.03	19	12	5	7	1,310,000	187,000	0	0	86
01.04 to 19.04	19	2	1	1	320,000	320,000	0	0	80

No. eggs : Number of eggs. $\overline{N}$ eggs/♀ : Number of eggs by female.

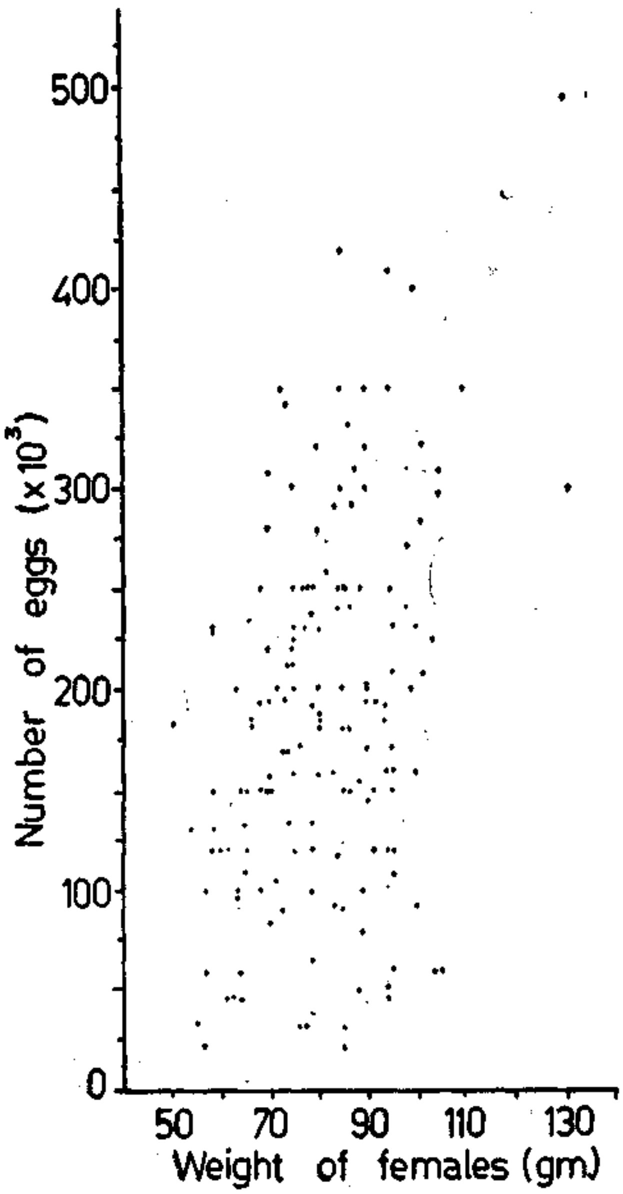

Fig. 3. Relationship between the number of eggs and weight in *P. monodon.*

— experiments on tank in complete darkness have been realized : some maturations have been obtained, but females don't seem to be fecundated by males and we never see fertilized eggs (Table 2).

The spawning process takes place between 8 p.m. and 1 a.m. in the tanks by sudden jumps and activities of the female. Then the pleopods actively disperse the newly extruded eggs. The number of eggs depends on the weight of the female from 60,000 to 600,000 for 45 to 130 g size animals. This number has not decreased in the successive generations (Fig. 3).

Ten hours after spawning the eggs under the microscope are of three types (AQUACOP, 1977) ; unfertilized with two or three big cells and many small ones ; normal fertilized eggs with a fecundation membrane and the presence of well developed nauplii with developing setae ; fertilized eggs in which development has stopped at various stages.

The percentage of normal eggs varies according to the spawning. It can reach 95% (Fig. 4).

Generally the totally unfertilized spawnings are due to lack of sperms in the thelycum but in some case it happens also with well impregnated females. This has been specially the cause in 1977 when the females were fed only with pellets and did not receive fresh food during the last days of the maturation process.

The larval rearing of *P. monodon* is one of the most difficult among the penaeid species. The larvae in our conditions are very sensitive to a bacterial disease causing rapid necrosis of the appendages (AQUACOP, 1977 a) mainly between Zoea (Mysis) II and P_5. In the absence of bacterial attack survival is around 80% at a density between 25 and 140 P_1/litre.

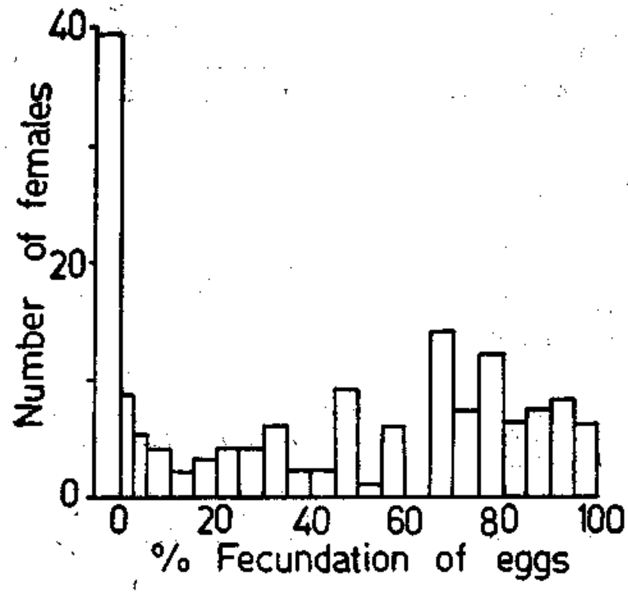

Fig. 4. Percentage of normal eggs produced in different spawnings.

DISCUSSION

The constitution of broodstocks is one of the essential pre-requisites to achieve reproduction in captivity. It is necessary to have all the year enough animals of appropriate size in good health, so that maturation can be induced. Right now we have selected the largest animals at the end of growth experiments in ponds or tanks. It appears that it would be better to rear the post-larvae and the animals which contribute the new broodstock in low density the animals which will constitute a new broodstock. The following results could be presented on broodstock development in a pond of 1,000 m^2.

— 1 pond with a stocking density of 4 animals/m^2 will furnish in six months an harvesting density of 3 animals/m^2 giving 3,000 shrimps between 20 and 40 g ; 1,500 specimens of larger sizes may be selected to stock (1.5 animals/m^2) in another pond so as to obtain an harvesting density of 1 animal/m^2 in 4 months giving 1,000 animals between 60 and 120 g.

It would take 10 months to constitute a new broodstock, and 1,000 animals would be reared in 8 maturation tanks for a 6 months period with a complete renewal of the animals every two months. Also a new broodstock must be started every six months.

Affording one result of spawning/month/female on a routine basis each tank will give a minimum of 4 millions eggs/month which would sustain a production of 2 millions P_5.

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SOME ASPECTS OF PRAWN CULTURE WITH PARTICULAR REFERENCE TO TIGER PRAWN *PENAEUS MONODON* FABRICIUS

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ABSTRACT

One of the most important problems encountered in prawn culture is the large scale and unaccounted mortality of the stocked prawns in the ponds. *Penaeus monodon*, the tiger prawn is one of the main species being cultured in India and its survival in the culture ponds is found to be about 20-30%. Some of the biological and physiological aspects of the prawn are examined in this study in order to improve the management of its culture. The important areas requiring attention are feeding and nutrition and its relationship to such factors as salinity and temperature, maintenance of required oxygen saturation level in the culture ponds by way of circulation system and prevention of cannibalism.

Experiments carried out on nutrition and feed have indicated that some specific feeds with main ingredients of cuttle fish meat and soyabean powder, gave the best growth returns and feed conversion at a temperature of 30°C and salinity of 7-10 ppt amongst the postlarvae. However, when these feed pellets are used in nature, under extensive field conditions proper utilization by the prawn must be ensured. As regards additional oxygenation of ponds when tidal water stops short of the farm, a slow water circulation device is suggested. Cannibalism poses a major problem in crustacean culture systems even when adequate food supply is present. In the penaeid mass culture systems a strategy of provision of removable hideouts as those developed for lobster culture is suggested.

INTRODUCTION

IMPORTANT strides are being made now in expanding prawn culture in India. Cultural activities have expanded to the extent where large number of private farmers *viz.*, both agricultural farmers and salt producers are accepting shrimp farming as a main crop as well as an ancillary one. The species involved in these cultural practices are primarily *Penaeus monodon* Fabricius and *Penaeus indicus* H. M. Edwards. Species like *Palaemon styliferus* (H. Milne Edwards), *Metapaneus dobsonii* (Miers), *M. monoceros* Fabricius and *M. brevicornis* (H. M. Edwards) and *P. semisulcatus* De Haan also contribute to a lesser degree to the production system of ponds. Experience has shown, however, that low survival and therefore the uncertainty of the end product remains the major hindrance to further expansion of prawn culture.

The biological and physico-chemical factors such as nutrition and feeding, stocking size and stocking density, stocking season and temperature-salinity requirements form one part of technology of prawn culture; the other, which India is yet to adopt, is the application of farm-engineering techniques to improve the habitat, the living environment of the animal. Laboratory experiments on *P. monodon* have shown that growth and survival are clearly linked with aeration (Rajyalakshmi *et al.*, MS 1). That means, it requires a certain saturation of dissolved oxygen level at all levels of feeding and growth. At the same time the oxygen saturation is related to temperature and salinity status of water. One other factor which has not been taken into consideration in the culture systems at all is the quality of the water as regards to its chemical purity. In extensive culture systems of India, the water is taken directly from its source *viz.*, creek, canal, backwater or estuary. Almost all the water sources of India are being put to multiple and uncontrolled uses. Now, however, a stage of usage has arrived where pollution monitoring is imperative before and after the water is taken into the farm.

A study is made in this paper of the various factors that are contributing to the low survival in pond systems; what are the technological gaps that have to be filled to improve the surival status and hence the production capacity of a given water body. The study uses data from the experiments conducted in the laboratory and field by the author, observations in other field conditions and data derived by work elsewhere in the world.

The author wishes to thank Dr. A. V. Natarajan, Director, Central Inland Fisheries Research Institute, Barrackpore who has encouraged this study and permitted its presentation in the present symposium.

Technological Gaps

Nutrition and feeding

It is in the current decade that workers in India have begun to give some status to nutrition and feeds in prawn culture systems. This aspect is extremely pertinent because our culture systems are extensive and the feed, whatever its quality, is directly broadcast into the pond where three interfaces are present *viz.*, the water, the soil and the quality of both.

In all earlier works, fertilization of pond has been given primary or even the sole importance following the practices and the techniques adopted in the fresh water fish culture.

Feeds and culture in experimental ponds

Fertilization and supplimental feeds: Experimental works in prawn culture conducted in different agro-climatic conditions of India have used basically fertilizers (NPK or cowdung) and supplemental feeds (wheat powder, oil cakes, rice bran and so on). These supplimental feeds also act as fertilizers. In recent years feed formulation has been started using pelletisation technique (Rajyalakshmi *et al.*, 1979; Varghese and Singh, MS). The present state of production utilizing such techniques is about 1145 kg/ha, in three crops per annum in three seasons: summer, monsoon and winter at Kakdwip Centre of Central Inland Fisheries Research Institute, Barrackpore, (Anon., 1978), 149 kg/ha/6 months at Kakinada Centre (Anon., 1978) and 514.7 kg/ha/80 days at Madras Centre (Sunderarajan *et al.*, 1979). While Kakdwip experiments used supplemental feed as well as organic fertilizers, the Madras experiments have used only organic fertilizers.

No comparison of production and growth rates is possible in the above results since the pond sizes, stocking sizes, stocking densities and duration of culture are quite variable besides the variability in physico-chemical conditions. The supplemental feeds given consisted of groundnut oil cake, rice bran, fish meal; the formula feed used at Kakdwip consisted of goat intestine (offal), algal powder, shrimp head meal and yeast as main ingredients. Percentage survival in these experiments ranged from 35-79. In some experiments the survival was in inverse proportion to growth (Anon., 1978).

Specific studies on feeds and nutrition of *Penaeus monodon* were conducted at Kakdwip fish farm using different feed formulations (Rajyalakshmi *et al.*, 1979; Rajyalakshmi *et al.*, MS 2). The pelletised feeds were used in the laboratory trials as well as in field (Tables 1 and 2). The protein percentage in the feeds was maintained at 20-36% using both plant and animal sources of protein (Table 1). Feeding rate was maintained 50-25% of biomass for postlarvae and 10-3% for juveniles at a temperature range of 29.5° to 35°C, salinity of 8.33 to 18.44 ppt and pH 8.0-8.96 in the field trials. The growth, from an initial weight of 0.16 mg, varies from a low of 3.5 g (feed II) to 19.5 g (feed IV). The survival was in inverse proportion, 77.9% to 35.9% in a growth period of 110 days.

4-5 m in height once every 13-15 days throughout the year. This water is rich in detritus as well as macroplankton. Certain species of prawn, especially in their estuarine sojourn, are detrivores (Rajyalakshmi, 1961). *P. monodon* also passes through this feeding phase. Regier (1972) characterised some estuaries as

TABLE 1. *Composition of various formulated feeds for* P. monodon

Ingredients		Feeds I	II	III	IV	V
Fish meal	..		30.0			44.4
Shrimp meal	..			4.0		
Squid meal	..				60.0	
Bombay-duck meal	..			6.0		
Groundnut oilcake	..		40.0			29.0
Wheat flour	..	20.0	30.0		19.0	24.2
Rice bran	..			85.0	20.0	
Maize flour	..	36.5				
Soyabean flour	..	35.5				
Brewer's yeast	..	5.0			0.2	0.2
Vitamin mix	..	1.0			0.2	0.2
Calcium phosphate	..	2.0			0.6	
Sodium hexa-metaphosphate	..			1.0		1.0
Sodium alginate	..	1.0				1.0
Conversion ratio in laboratory trials	..	2.4	6.6	3.8	2.5	6.0

TABLE 2. *Growth (production) of* P. monodon *in field trials using formulated feeds*

Ponds	Feeds	Growth/day mm	Survival %	Production Kg/ha/110 days	conversion ratio
1	I	0.8	77.9	172.45	2.4 : 1
2	II	0.6	70.9	109.75	6.0 : 1
3	IV	1.8	35.9	239.00	2.5 : 1

Detritus from natural sources as feed: Another important supplemental feed source is the micro-organisms and detritus brought in through the water source. Farms located along the Hooghly estuarine system receive fresh exchange of water through spring tides, detritus based estuaries, with vascular plant detritus and a component of fresh benthic organisms. The Hooghly estuarine system can be classified as one. Odum and Heald (1973) mention that the key organisms in this food web are a group of detritus consumers herbivorous and omnivorous crustaceans, molluscs, insect larvae, nematodes, polychaetes and a few fishes. Qasim and Sankaranarayan (1972) showed that the caloric content of detritus range from 250-400 cal/g dry weight. The energy budget of *Metapenaeus monoceros* using detritus as food showed net and gross efficiencies as 21.6 and 24.1% respectively (Qasim and Easterson, 1974).

Thus, three sources of food can be identified in the culture systems: fertilization, supplemental feed and natural feed (detritus and macroplankton) in the intake water. Quantification of each would provide an answer to the quantitative and qualitative feed, both to avoid wastage and putrefaction at pond bottom, keep the feed costs low and regulate the feeding techniques.

Caillouet *et al.* (1974) used wheat bran in their experiments as an artificial detritus-producing base. They further mention that with wheat bran feeding, it seemed possible to raise postlarval pink shrimp in ponds or tanks to about 4 g in three months in stocking densities as high as 100,00 per ha with survival as high as 90%. When compared to production cited in Indian studies, the growth of 4 g/3 months is extremely low; however, this study indicates the importance of detritus as feed. They mention that this method of feeding is much simpler than the feeding of pelleted feeds 'since the former does not depend upon monitoring of growth rates of population densities to determine feeding rates.'

Feed in Bheri or impoundment culture

In this type of culture system which follows a wild culture practice, the deteritus-macroplankton chain is the only food source. However, several *Bheries* have developed along the sewage canal of Calcutta Sewage System. This canal opens into one of the minor estuaries of the Hooghly estuarine system called the Kulti Estuary, about 30 km away (Ray and Pakrasi, MS). The *Bheries* utilise the raw or diluted sewage, according to their location, as a fertilizer in their farms. Ray and Pakrasi (MS) have also estimated the nitrogen/phosphorous ratio at each level of dilution in this sewage which would enable the farmer to utilise the sewage at such dilution levels when its fertilization value would be higher. The production of prawn component in this system and their survival has not been reported yet.

This type of recycling of waste has long been in practice in Far-Eastern countries and is reported to give high yields in freshwater carp culture systems. This needs detailed study for use in prawn ponds.

Development of new techniques of feeding

Quality of protein : In the field of improved technology for shrimp culture the new directions pertain to formula feeds with not only quantified protein but also the protein quality.

The development have been reviewed by New (1976) wherein the importance of different amino-acids in formulated feeds was shown. This qualifies the protein that is needed for feed formulation of each species of prawn. A requirement of similarity of amino-acid profile of the animal to that of the animal fed also seem to improve the growth component of the animal (Phillips and Brockway, 1956).

Quantity of protein: High level protein requirement of 50% or more is not a requirement of all prawns. For instance, the 50% or more requirement of *Penaeus japonicus* (Deshimaru and Shigueno, 1972) is interpreted as probably due more to its more predatory behaviour than many penaeids (Liao and Huang, 1972). In *Penaeus monodon* our findings showed that a protein level below 40% is showing a fast growth rate to marketable sizes. The growth rate is a good criterion for assessing the nutritive value of feeds. It thus shows that species-wise requirements should be based on their feeding habits. *P. monodon* is not a predator, its gut contents showing higher percentage of detritus, mud and benthic algae.

In the feed formulation done at Kakdwip Research Centre of the Central Inland Fisheries Research Institute (Rajyalakshmi *et al.*, 1979) it has been shown (Table 2) that the cuttle fish meal and soyabean meal resulted in best growth performance (as measured by feed conversion ratio) both in laboratory as well as field studies. The plant product, soyabean is known to have an amino-acid profile more similar to that of the prawn, *Penaeus japonicus* than that of an animal such as *Artemia salina* (Deshimaru and Shigueno, 1972). Other feeds which fulfilled this requirement was the squid and a clam, *Corbicula manillensis.*

Other studies showed that the larger the shrimp, the more food they eat. This was inferred from observing the food conversion ratio values and increment of weight (Shigueno, 1975). The food preference of marine shrimp was found to be, in order, oyster meat, nereid, squid, mantis-shrimp meat, goby and mackeral (Liao and Huang, 1970). Fresh frozen diet always yielded better growth than dried food.

Energy and protein relationship : AQUACOP (1976) estimated that total energy content of 3.3 k cal/g was required for optimal growth of *P. monodon* with a diet containing 40% protein. Sedgwick (1979) mentions in this connection that protein sparing may be effective in reducing costs of feeding. His experiments on *P. merguiensis* showed 'that variations in the ratio of energy to protein in the diet may influence food consumption, protein utilisation and the efficiency of food conversion.' In experiments on *P. indicus* also (Colvin, 1976) the substitution of protein by potato starch, involving a small change in calofic ratio (4.8-4.7 k cal/g) did not significantly affect growth although the protein reduction was from 53.1 to 42.8%. The energy protein relation may help thus in reducing costs in culture experiments.

Dissolved oxygen level and aeration techniques

Dissolved oxygen levels in extensive pond systems : The management of water and soil quality is highly pertinent to shrimp culture systems. This emphasis is necessary taking into consideration the behavioural characteristics of prawns. They are bottom living forms, moving over the bottom searching and 'feeling' for food with their chelipeds. Therefore, when the bottom conditions become slushy with waste feeds and other settlings, the habitat deteriorates accounting for higher mortality. Such putrefaction of bottom was observed often in the experimental ponds in Kakdwip (where the pond bottom is made up of mud with low sand content) at the time of harvesting when all the water is pumped out. Unfavourable weather conditions such as sudden rainfall after a strong sunny day or windless conditions also accelerate conditions of pollution.

The brackish or coastal aquaculture farms of India depend on the tidal exchange of water by gravitational flows. This exchange is expected to supply both oxygen-saturated water as well as remove the metabolite filled water from the ponds when the tide reverses. Often the location of the pond is such that the water supply is possible only at the peak spring tide which occurs at intervals of 13-15 days only. The amplitudes of tide at latitudes where the Hooghly estuarine system is located makes it possible to locate a farm even upto 70 km from sea mouth. Thus, a good water change is possible for 2-3 days in each fortnight. This set of conditions does not prevail elsewhere in southern parts of India. This requires farm engineering techniques to take care of water supply and water circulation to freshen up the oxygen saturation.

Rajyalakshmi *et al.* (MS 1) conducted experiments on interaction of aeration/density to survival using post-larvae of *P. monodon.* Two variables were considered *viz.*, with aeration and without aeration. quantification of air supply could not be done in this study. The results indicated that the effect of aeration on growth was favourable while it was not very favourable for survival even at low densities. Further study is required to know whether reduction of aeration rate could have increased the survival level. Intermitant and slow aeration appeared to be more preferable than continuous or stronger rates. Aeration as a culture management technique would be highly suitable in aeras where water exchange is not always possible. The importance of such techniques to maintain dissolved oxygen in the culture system as well as the animals in it is well documented (Spotte, 1970). Aeration can also lead to improved water quality by removing ammonia and hydrogen sulphide formations which might occur in cases of overfeeding and so on, as mentioned above. Nuisance algal blooms also might be eliminated. An efficient design of aeration has to be worked out for intensive pond systems.

In pond culture of *P. monodon* it is better that the nursery ponds are not continued for use of prawn culture to marketable sizes. The young ones are to be harvested and then changed over to another pond. After continuous use of 1-2 months for nursery rearing, the waste supplimental feed, fertilizer, etc., create very unhealthy pond bottom, full of black surface slimy mud with emanation of hydrogen sulphide and general anaerobic conditions. This causes both retardation of growth as well as high mortality. Another factor noticed is that some of the larger ones tend to get more and more settled inside mud with pleopods clogged with algal growth and hence become unsaleable. This bottom condition is an important parameter to be considered when, for instance, raw sewage is being used in culture systems. Monitoring of pond bottom is therefore absolutely necessary.

The recirculating system, flow-through system, etc.: The advantage of culturing organisms in recirculating systems with high density is now well recognised especially in molluscan rearing systems. The parameters to be monitored for maintaining water quality are quite complex, *viz.*, nitrates, nitrites, ammonia, reactive phosphorus, chlorides, dissolved oxygen, pH, alkalinity, salinity, etc. (Epifanio and Mootz, 1976). For high density nursery rearing it could be quite a suitable system.

Currently the juveniles of prawns are being collected from nature and transported to farm site often resulting in heavy mortality. If these juveniles, collected from natural sources or from hatchery rearing, are first introduced into recirculating system for a period of a month or so and then transferred to extensive pond systems, better survival is ensured.

The recirculating system also could show possibilities in raising shrimp to marketable sizes. Normally, as dictated by nature, our pond growout systems are limited to durations of 90 days (from post-nursery rearing phase or, say from 0.5 g size) to 180 days in some cases or 240 days in another (Anon, 1978). The percentage survival ranges from 31 to 80. The recirculating system whether in open ponds or in highly controlled laboratory systems might open up new venues for: (i) for marketable rearing, (ii) for increasing stocking density, (iii) or for keeping the stocking density normal (*i.e.* as followed in the field, at a rate of 20-30,000/ha) but prolonging the rearing period or till such time the prawns attain better average counts of 15-20/kg instead of the present 30-60 nos/kg (whole counts). Here farm-engineering techniques have a very important role to play, *viz.*, by introducing proper techniques of recirculation, filtration of algal or other growth and proper circulation pattern as per the requirements of prawns. Fast flow may create problems of feeding of prawns, oversaturation of water and changes in pH level, etc. High density rearing from juveniles to marketable sizes in closed systems is another development in culture systems (Mock *et al.*, 1974). In this system once again, recirculation plays an important role as a waste removal technique.

Selection of Compatible Species in Polyculture Systems

One more field of study that still needs to be done is the proper utilization of the pond niches, both for feeding as well as for hiding, moulting, breeding and so on.

Compatibility at all levels or at all stages of life might not be possible in all species. It is now well recognised that prawns, especially *P. monodon* require an independent nursery management phase. Before the post-larvae are put into nursery management phase they pass through four types of stresses : (i) collection and transport to place of stocking; (ii) segregation of post-larvae from total collection which at times take 3-4 hours; (iii) handling and agitation and (iv) infusion to other waters.

Observations of collections made at Muriganga Estuary near the Kakdwip laboratory showed that the post-larvae of *P. monodon* are hardier than the young juveniles of *P. indicus* which seemed to die faster. Even then unless all the four stresses, mentioned above are cleared as early as possible mortality would ensue. With proper handling and nursery management 90% survival has been reported (Ravichandran *et al.*, MS). In culture to marketable sizes proper experimental studies are lacking to make any firm observations. However, taking the information obtained through polyculture of finfiish and prawns. Rajyalakshmi (1978) reported on the growth rates of *Penaeus monodon*; the combination with *Chanos chanos* gave a comparatively greater growth rates (12-15 g initial to 60 g final in 120 days), than with exotic carps and mullets or with mullets alone. In the low saline ponds (at Bokhali Fish Farm of the Central Inland Fisheries Research Institute, Barrackpore) *P. monodon* was stocked in combination with freshwater exotic carps (*Cyprinus carpio* and *Hypophthalmix molitrix*) and mullets (*Liza tade* and *Liza parsia*) ; the growth increment with this combination was higher (4.11 g initial to 74.6 g final in one year rearing time) than with mullets alone (10.7 g initial to 39.5 g final in 270 days rearing time) (Rajyalakshmi, 1978). However, the stocking rates, sizes, hydro-ecological and pond sizes, etc., are not statistically comparable.

One experiment using post-larval *P. monodon* and juvenile *Liza parsia* (13 mm and 15 mm respectively) was conducted in four 0.02 ha ponds at Kakdwip (Rajyalakshmi *et al.*, MS). The results indicated that growth of *P. monodon* might have been much better if *L. parsia* were not in the system. Both seem to compete for the same food *i.e.* detritus and benthic organisms. At the end of 110 days of rearing, the production was 355.75 kg/ha with Feed IV (Table 1) in which *P. monodon* contributed 239.00 kg/ha.

Hide-outs and other Protection Measures for Moulted Prawns in Culture Ponds

Other technologies which are of equal importance in survival of prawns in culture systems are of physical nature. Taking cognizance of the moulting habit of the crustaceans, when they are immensely vulnerable to predation, cannibalism and disease, this parameter has to be given due importance.

Proper hide-outs can be of concrete, of a bunch of roots, boulders to mention a few. These provisions, however, should be considered in combination with harvesting techniques. They should not interfere with each operation or the hide-outs should be of removable types.

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MASS PRODUCTION OF JUVENILES OF FRESHWATER PRAWN *MACROBRACHIUM ROSENBERGII* IN FRENCH POLYNESIA : PREDEVELOPMENT PHASE RESULTS

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ABSTRACT

Since 1973, a new method for mass production of *Macrobrachium rosenbergii* post-larvae has been set up in French Polynesia in CNEXO-COP centre in collaboration with Territorial Fisheries Service.

The larvae are reared in clear water daily renewed, without phytoplankton and at high density (100 to 120 larvae per liter in conical bottom tanks of 0.8 and 2 m^3). 90 post-larvae per litre are obtained within six weeks on a diet of *Artemia* nauplii and inert particles. Since 1976, a pilot hatchery is working and ten pilot scale productions gave 4.6 million juveniles demonstrating the reliability of this method. The technology is described and the production costs discussed.

INTRODUCTION

SINCE 1973, the CNEXO-COP aquaculture team, in collaboration with the Fisheries Service of French Polynesia is setting up an original technology for mass production of *Macrobrachium rosenbergii* post-larvae ; after an experimental phase (1973-1976) for exploring the basic parameters of the technology and going through the problems, and a pilot phase (1976-1979) for evaluating the costs, we are now moving to a production scale hatchery, which will provide the local farmers with post-larvae (15 millions post-larvae per year).

As far as possible all the parameters are controlled (temperature, salinity, water quality, food quantity and quality, sanitation, light). The experimental phase showed that these controls are better performed at high density (100 larvae/litre) and in clear water.

PRODUCTION TECHNOLOGY

Since hatchery technology is described in details elsewhere (AQUACOP 1977 a, b), only a brief summary is given here.

For broodstock, about 3,000 female and 1,500 male prawns, generally larger than 30 g in weight, are maintained in three 1,000 m^2 earthern ponds ; a fourth pond is used to grow out the juveniles till reproduction size. As long as water temperature remains above 23°C, this broodstock provide in a week a minimum of one hundred gravid females with dark grey (nearly ready to hatch) eggs. The females

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seined from the ponds are placed in 2 m^3 circular tanks at 4 ppt salinity and within five days release more than 1,000,000 larvae.

After hatching, the larvae are reared in cylindrical tanks with conical bottom and central aeration. The hatchery includes experimental tanks of 0.8 m^3 and production units of 2 m^3. Larvae are stocked in the tanks at initial density of 100 larvae/litre and production is nowadays routinely greater than 90 post-larvae/litre in 42 days.

TABLE 1. *Inert food composition (% of dry weight)*

Squid flesh ..	20
Shrimp flesh ..	10
Hen eggs ..	20
Herring roe ..	20
Vitamin mix ..	2
Mineral mix ..	1
Cod liver oil ..	15
Alginate ..	12

Salinity of the culture water is increased from 4 ppt at hatching to 12 ppt and temperature is maintained at 29-31°C. The mixture of fresh and seawater first chlorinated and filtered is used to completely exchange each rearing tank once a day at 1600 hours.

zoea 6 and the *Artemia* nauplii after the daily water exchange from late stage zoea 2. The amount of food given is adjusted according to consumption, which may vary widely around the standard given in Table 2.

Post-larvae are harvested from each tank at the 32nd and 40th days. They are transferred to 2 m^3 cylinder tanks where the salinity is dropped to zero within 24 to 48 hours. After acclimation to freshwater the prawns are sent to grow-out ponds; their average weight is 8-15 mg at this time.

To avoid bacterial contamination and resulting mass mortalities, the hatchery is washed out and allowed to dry for three days between production runs. Antibiotics (chloramphenicol, penicilline-streptomycine, terramycine, 1 to 20 g/m^3) are used if bacterial diseases appear during larval culture, and preventively at appearance of first post-larvae.

The hatchery labour force consists of a technical manager and two to four assistants. Two workers can manage eight to ten tanks per day and the amount of labour required is virtually the same for both 0.8 and 2 m^3 tanks. However, for continuous daily management of eight production tanks, a squad of four would

TABLE 2. *Standard amount of daily feeding rate, according to the stage, for a thousand larvae*

	1	2	3	4	5	6	7	8	9	10	P.L.
Artemia nauplii (number in thousands) ..	0	5	15	20	25	35	45		45		35
Inert food (mg dry weight) ..	0	0	0	0	0	.08	.12		.15		.12

The larvae are given two types of food: inert particles (compositions and amount given in Tables 1 and 2) and newly hatched *Artemia* nauplii. The inert food is given from 0800 to 1400 hours in two to four meals from stage be recommended because of the normal five day work week and occasional absenteeism. About one third of the labour is for feeding, one third for observations and countings and one third for water changing.

Production Results and Costs

Total survival has increased from an average 45% for the first pilot assays to an average of 92% for the last two (Table 3) in the standard conditions.

Cost: For estimating the budget of the future production hatchery, using solar energy for heating, computations were made according to a projected production of 15 millions/year (7 productions of 2.1 each) and in accordance with the last results obtained. The investment for such a hatchery is estimated at $ 292,000 (Table 4). All the figures are from proforma invoices on a mid 1979 basis. Amortization is computed linearly for 20 years for housing, 5 years for mechanical fittings, plastic tanks, freezer, mixer-liquefier, microscope, measurement fittings.

The projected yearly budget ($ 139,000 or $ 9.27/1,000 post-larvae) is computed in accordance with the two last assays on Table 5. Social insurances, holiday bonuses and management costs are all included in the labour costs. Energy costs are computed by multiplying the power of every electrical fitting by the number of hours each one worked and adding on 10% for electrical loses in the circuit.

TABLE 3. *Results of the pilot scale assays*

Number of assay	1	2	3	4	5	6	7	8	9	10
Raising duration (days)	60	54	66	46	40	40	41	40	44	40
Average temperature (°C)	27	28	26	29.5	30	30	29.5	30.5	30	30.5
Raising volume (m³) ..	8x.8	5x.8 3x2	4x.8 1x2	7x.8 4x2	4x.8 4x2	4x2	2x2	5x2	5x2	2x2
Initial number of larvae (thousands) ..	835	1187	448	1774	1135	841	385	1070	1065	434
Number of larvae at 1st post-larvae occurrence (thousands) ..	×	987	192	883	1000	841	385	763	1065	434
Number of post-larvae produced (thousands)	390	520	37	550	600	610	205	288	1006	396
Survival (%) ..	47	44	8	31	53	72	53	27	94	91
Number of post-larvae produced per litre ..	61	52	7	40	54	76	51	29	101	99

Discussion

The technology developed in Tahiti differs mainly from others developed in Hawai (Fujimura, 1967-75) and Taiwan (Nai-Hsien

TABLE 4. *Projected initial investment for an hatchery of 15 millions post-larvae yearly capacity (in US $ mid 1979 estimation)*

		Initial cost	Amortization Annuities
Broodstock ponds (4 × 1,000 m²)	..	70,000	3,500
Hatchery building (300 m²)	..	66,000	3,300
Solar heating system	..	60,000	6,000
General store and service building (100m²)	..	10,000	500
Spawning and post-larvae storage tanks (10 × 5 m³)	..	8,000	1,600
Raising tanks (+ accessories) (12 × 2 m³)	..	20,000	4,000
Treatment reservoirs (2 × 30 m³)	..	10,000	2,000
Water pumps and pipes	..	22,000	4,400
Air suppressor and pipes	..	4,000	800
Laboratory apparatus	..	10,000	2,000
Food storage and preparation	..	6,000	2,000
Miscellaneous	..	5,000	1,700
		292,000	31,200

TABLE 5. *Projected yearly hatchery budget for production of 15 million Post-larvae per year (US $ mid 1979 prices)*

Salaries	1 biologist	..	30,000
	2 technicians	..	22,000
	3 workers	..	21,000
Food	Alginate diet (2 000 kg wet)	..	5,000
	Artemia cysts (200 kg)	..	10,000
Antibiotics (10 kg)		..	1,000
Energy (55,000 KWh)		..	11,000
Broodstock maintenance, salary		..	7,000
food		..	800
Investment annuities (as in Table 4)		..	31,200
			139,000

US $ 9.27/1 000 Post-larvae.

Chao and I-Chiu Liao,1977), by a higher density and no phytoplankton in the water, this technology allows a close control of the rearing procedures and conducts in standard conditions, to obtain constant results. In case of bacterial attacks or epiphytes or epizooty, more effective treatments can be done due to the small volume of the rearing tanks.

In the projected yearly budget, the cost of labour is the major expenditure in the operation (58% of the total) and the skill and efficiency of those employed the major reasons for its success.

Water treatment through biological filters which gives good results on experimental scale could be used in the future on the production scale. The daily water changing will be suppressed and the heating greatly reduced; a three men team (one biologist and two technicians) then will run a 12 tanks hatchery all year round; the cost will be lowered approximatively to $ 7.5/1,000 post-larvae.

Many prices in French Polynesia are higher than in other tropical places, especially salaries; almost everything must be imported and long distance shipping and high import taxes increase all prices of goods by an average of 66%. It can be assumed that in other country, the production cost could be greatly reduced.

CONCLUSION

The technology set up by the CNEXO-COP aquaculture team (AQUACOP), in co-operation with the French Polynesia Fisheries Service, is now on a production scale. The projected production cost ($ 9.27/1,000 post-larvae) seems low enough to go on to commercial scale. The reliability of the technology is high due to the control of all the parameters and the skillness of the technicians.

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INFLUENCE OF THREE STOCKING STRATEGIES ON THE PRODUCTION OF PRAWNS *MACROBRACHIUM ROSENBERGII*, FROM PONDS IN SOUTH CAROLINA, U.S.A.*

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ABSTRACT

The effects of three stocking strategies on the production of prawns *Macrobrachium rosenbergii*, were examined in six 0.25 ha earthen ponds in Bonneau, South Carolina, during a five-month growing season. The strategies consisted of stocking replicate ponds with either postlarval prawns, a mixture of postlarvae and juveniles or juveniles only. The comparisons were tested at the same densities (64,600 prawns/ha^{-1}). Prawns were fed with a prepared ration once daily and seine-sampled every four weeks. Ponds were harvested by complete drainage at the end of the growing period.

Growth and survival rates were generally similar. Prawns in the post-larvae stocking strategy grew from a mean size of 0.09 to 17.7 g with a survival rate of 72.4% as compared to a growth rate of 0.65 to 23.1 g with 70.9% survival for the mixed stocking strategy and from 0.51 to 22.7 g and 77.4% survival for the juvenile only strategy. Gross production was similar (1,204 vs. 1,207 kg/ha) with the mixed size and juvenile only strategies and approximately 43% greater than that obtained from the post-larvae only strategy. Feed conversions were similar (2.20 vs. 2.24) for the mixed population and juvenile only treatments and better (1.71) for the post-larvae only treatment. Sex ratios were significantly different ($P \leq .001$) than 1 : 1 only in the ponds stocked with the mixture of post-larvae and juveniles ; in these ponds there were a greater number of females.

At harvest, female prawns displayed a relatively normal, unimodal size distribution whereas the males exhibited a typically multimodal, skewed distribution. On the average, males contributed 9-17% more in total biomass at the harvest than females. However, overall production of tail biomass was similar for both males and females because of the higher processing (head) loss for males. Tail weight distributions at harvest were greatly influenced by stocking strategies. Only 24% of the tail weight produced in the post-larvae stocking strategy was contained in the larger more valuable size classes ($\leq$ 12.6 g tails) as compared to 44 and 48% respectively, for the mixed and juvenile only strategies.

Our data suggest that in areas where the growing season is $\leq$ 5 months the stocking of small juveniles ($\sim$0.5 g) or a mixture of post-larvae and juveniles in ponds at low density ($\sim$ 6.5/m^2) should result in profitable prawn farming.

INTRODUCTION

POND CULTURE of Malaysian prawns *Macrobrachium rosenbergii*, has become commercially attractive since Ling (1962) first closed the life cycle and Fujimura (1966) demonstrated mass rearing techniques for juveniles. Development activities have been centered in tropical areas (Goodwin and Hanson, 1975 ; Ling and Costello, 1976 ; Hanson and Goodwin, 1977) where year-round culture is possible, but interest in more temperate areas is also significant (Sandifer and Smith, 1974, 1976 ; Cohen, 1976 ; Smith *et al.*, 1976 a, 1978 ; Willis and

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Berrigan, 1977). In tropical areas prawns are selectively harvested on a regular basis from continuous production ponds (Fujimura, 1974), whereas in temperate areas pond drainage and batch harvest is the rule (Smith *et al.*, 1976 a). A basic production model for prawn farming has been developed for implementation in South Carolina and other temperate areas (Sandifer and Smith, 1976). This model consists of four phases: (1) a *hatchery phase* in which post-larvae are produced in indoor saltwater tanks during winter and spring; (2) a *nursery phase* in which post-larvae are reared to larger juveniles at very high population densities in specially designed nursery systems; (3) a *production phase* in which marketable prawns are produced seasonally in grow-out ponds, batch-harvested and processed for market; and (4) a *brood stockphase* in which brood prawns are selected and maintained indoors to provide larvae for the next hatchery production cycle (Fig. 1). This production plan is shown on an annual cycle for South Carolina in Fig. 2. The technical feasibility of these various phases has been demonstrated (Smith *et al.*, 1976 b, Sandifer and Smith, 1977, 1978; Smith and Sandifer, 1979) and economic analysis of the production model is underway.

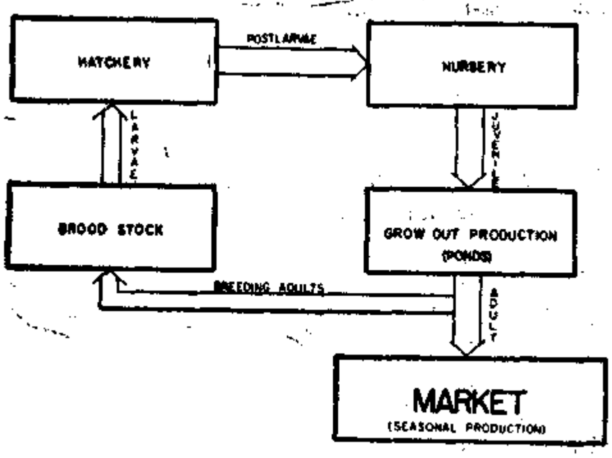

Fig. 1. A production model for rearing Malaysian prawn in South Carolina and other temperate areas.

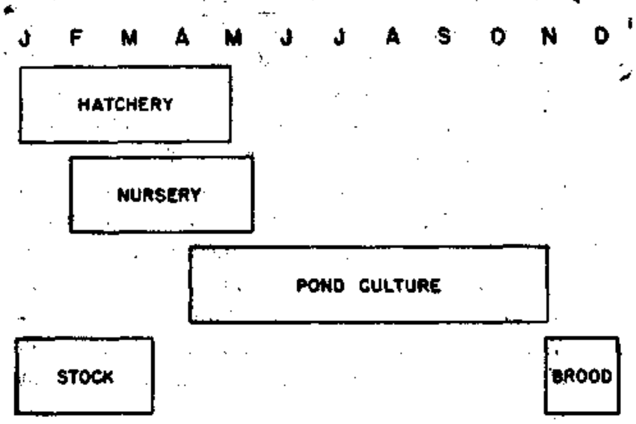

Fig. 2. Annual production cycle for rearing Malaysian prawn in South Carolina.

Preliminary analysis of the pond grow-out phase indicated that population structure of the harvest and feed costs were of major economic importance (Roberts and Bauer 1978). Thus, efforts during the 1978 growing season were directed towards examining the influence of three stocking strategies on the production of prawns, both quantitatively and qualitatively, and the economic implications. This paper provides the biological results obtained with the various pond stocking strategies.

We thank all our mariculture staff especially Alvin Stokes, Wallace Jenkins and Todd Nimmich for their dedicated assistance in the conduct of this study. Jack Bayless provided the ponds and he and Dick Zimmerman helped in many ways throughout the rearing season. Karen Swanson and Frank Taylor prepared the figures and Pete Laurie provided photographic assistance. Virginia Hargis typed the manuscript.

Materials and Methods

Pond description and preparation

The rearing trials were conducted in six 0.25 ha earthen ponds at the S. C. Wildlife and Marine Resources Department's Dennis Wildlife Center in Bonneau, South Carolina. These ponds, approximately 150 × 17 m size, are similar in construction and have been used for culture activities since their construction in 1974. The levees are sloped 3 : 1 and water depth ranges from about 50 cm at the shallow end to 112 cm at the harvest basin (mean depth 97 cm). The soil texture is a sandy clay loam. Prior to filling, ponds were limed with dolomitic agricultural limestone at a rate of ~ 1,500 kg/ha so as to raise the soil pH from ~ 5.4 to 6.0. Water for filling and flushing the ponds was either pumped or gravity flowed from an adjacent 22,000 ha reservoir. After flooding the ponds, a 20-20-5 fertilizer (20% nitrogen : 20% phosphoric acid : 5% potash) was added once at a rate of 112 kg/ha to induce a phytoplankton bloom.

were low or expected to be low (< 2 ppm) feeding was rescheduled for mid-morning or withheld completely as occurred on 4 days during August-September. Temperature and dissolved oxygen were monitored daily and complete water quality analyses were performed weekly in each pond. These data are summarised in Table 1 and Fig. 3.

At the end of the growing period, ponds were drained and all prawns weighed and counted. Next, 10% of each population was taken and each animal in this random sample was individually measured and examined. Prawns were measured to the nearest 1.0 mm from orbit of eye to tip of telson, then blotted and weighed to the nearest 0.1 g on a Mettler electronic balance. All population data (*i.e.*, sizes, sex

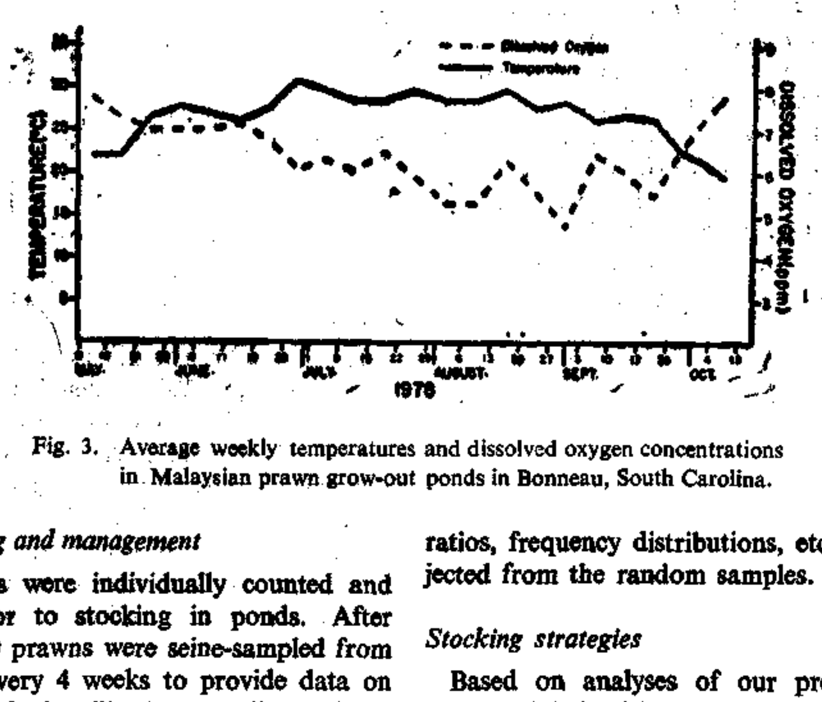

Fig. 3. Average weekly temperatures and dissolved oxygen concentrations in Malaysian prawn grow-out ponds in Bonneau, South Carolina.

Pond stocking and management

All prawns were individually counted and sampled prior to stocking in ponds. After stocking, 300 prawns were seine-sampled from each pond every 4 weeks to provide data on growth and feed utilisation. Daily, Ralston Purina Marine Ration 25 (25% protein) was broadcasted along the length of the pond late in the afternoon. At 4 week intervals the amount of feed was adjusted according to the sample data. When dissolved oxygen levels

ratios, frequency distributions, etc.) were projected from the random samples.

Stocking strategies

Based on analyses of our previous pond culture trials (Smith *et al.*, 1978), three stocking strategies were compared as to effectiveness in producing large, high value prawns and low seed stock costs. The stocking strategies were : (1) stocking post-larvae (< 0.1 g) alone ; (2) stocking 50 : 50 mixture of post-larvae and

TABLE 1. *Mean water quality data for Malaysian prawn grow-out ponds in South Carolina in 1978. Data were obtained from water samples taken near the pond bottom at or prior to 0700 hours*

Pond No.	Dissolved[1] (Oxygen (mg/l)		pH[2] Bottom		Water[3] Temperature (°C)		Total Alkalinity[4] (mg/l)		Hardness (mg/l)[5] Total		Hardness (mg/l)[5] Calcium		Free CO_2 (mg/l)[6]	
	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range
21	6.7	3.8-11.4	8.4	7.0-10.0	26.6	18.0-36.5	51	35-70	75	50-100	30	25.50	9.0	5.0-17.5
22	6.4	3.2-10.0	7.5	7.3- 7.9	27.0	18.0-35.0	45	30-60	85	50-125	30	25-50	11.5	10.0-17.5
23	6.2	2.5- 9.7	7.4	7.0- 7.8	27.0	18.1-34.8	49	30-60	70	50-100	25	25-25	12.5	10.0-17.5
24	5.9	0.4-10.4	7.7	7.0- 8.1	26.9	17.1-33.8	50	40-60	70	50-100	35	25-50	11.0	5.0-17.5
25	5.6	3.2- 9.3	7.4	7.2- 7.7	26.9	17.2-33.7	53	35-60	75	50-100	30	25-50	12.0	7.5-17.5
26	6.7	4.6- 9.3	7.4	7.0- 7.8	26.8	17.9-33.6	53	45-60	75	50-125	30	25-50	12.5	10.0-17.5

[1] D.O. measured with YSI oxygen meter and probe, model 57.
[2] pH measured with a LaMotte Chemical Co. test kit, model P-5100.
[3] Temperature measured with YSI D.O. meter, model 57.
[4] Alkalinity measured using a LaMotte Chemical Co. test kit, model WAT-HPS.
[5] Hardness measured using a LaMotte Chemical Co. test kit, model PHI-CM.
[6] Free CO_2 measured using a LaMotte Chemical CO. test kit, model PCo-5.

small juveniles; and (3) stocking all small juveniles. Strategies were compared at the same low density (64,600 prawns ha^{-1}) and replicated in two ponds. The various stocking strategies were randomly assigned to six ponds.

Results

Growth, survival and production

The various stocking strategies were compared during a five-month rearing period, with similar results obtained within treatments (Table 2). Postlarval prawns grew from a mean size of 0.09 to 17.7 g and had a survival rate of 72.4%. Prawns in the mixed size stocking strategy grew from 0.65 to 23.1 g with a 70.9% survival rate while the prawns in the juvenile only strategy grew from 0.51 to 22.7 g and exhibited a 77.4% survival rate. Growth curves were relatively similar with differences most directly attributable to initial stocking size (Fig. 4). The apparent decrease in size during the last two weeks of the grow-out period probably reflects seine sampling bias. Production rates for the mixed size and juvenile only stocking strategies were very similar (1,204 vs. 1,207 kg/ha) and approximately 43% greater than that obtained from the post-larvae only stocking strategy (Table 2).

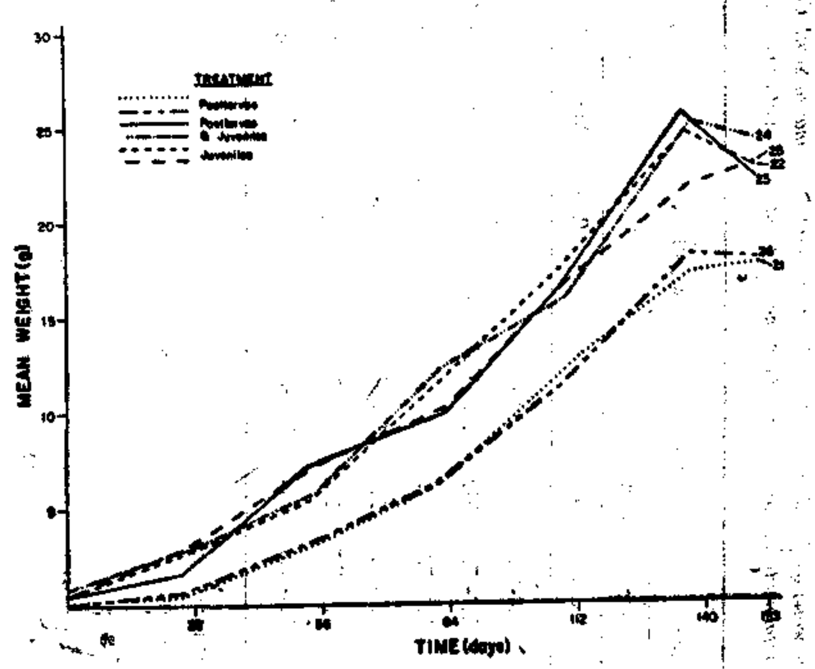

Fig. 4. Growth curves for *Macrobrachium rosenbergii* reared in ponds under three stocking strategies.

Production analysis

The population distributions of the harvested crops for the various stocking strategies were examined in detail. Examination of the crops according to various market categories indicated that tail weight distributions for the mixed size stocking strategy and juvenile only strategy were similar with about 40% of the tail weight contained in the largest size classes (< 36 count tails). In contrast, in the post-larvae only stocking strategy only 24% of the total tail weight was contained in these larger tail count categories (Table 3).

Males provided from 9.1 - 17.0% greater whole prawn production than did the females.

TABLE 2. *Summary of stocking and production data for pond-reared Malaysian prawn produced under three stocking strategies in 1978*

Pond Data			Stocking Data				Harvest Data					
Stocking Strategy	Replicate Number	Surface Area (ha)	Date	Prawns per Pond	Mean Size (g)	Density (#. m-2)	Date	Elapsed Days	Survival (%)	Mean Size (g)	Kg/ha	Feed Conversion[2]
Postlarvae	1 (Bon/21/78)	0.25	10 May	16,230	0.11	6.46	12 Oct.	153	74.4	17.4	848.6	1.66 : 1
Postlarvae Mean	2 (Bon/26/78)	0.25	10 May	16,230	0.07	6.46	12 Oct.	153	70.4	17.9	832.1	1.75 : 1
Mean					0.09				72.4	17.7	840.3	1.71 : 1
Postlarvae + Juveniles	1 (Bon/23/78)	0.25	9 May	8,115 8,115	0.09 1.02	6.46	11 Oct.	153	69.1	22.1	1,157.2	2.33 : 1
				16,230	0.56[1]							
Postlarvae + Juveniles	2 (Bon/24/78)	0.25	9 May	8,115 8,115	0.09 1.40	6.46	11 Oct.	153	72.6	24.1	1,250.7	2.06 : 1
				16,230	0.75[1]							
Mean					0.65[1]				70.9	23.1	1,203.9	2.20 : 1
Juveniles	1 (Bon/22/78)	0.25	8 May	16,230	0.51	6.46	10 Oct.	153	77.6	22.7	1,196.3	2.22 : 1
Juveniles	2 (Bon/25/78)	0.25	8 May	16,230	0.50	6.46	10 Oct.	153	77.2	22.7	1,217.3	2.26 : 1
Mean					0.51				77.4	22.7	1,206.8	2,24 : 1

[1] Data are weighed means.
[2] Feed conversion equals number of units of feed (dry weight) used to produce a unit of prawn biomass (wet weight).

However, after the heads were removed the portion of the tail weight provided by the males and females was similar for all strategies (Table 4). This resulted because the males had a slightly lower tail weight yield (range 44.4 - 46.7 vs. 50.6 - 51.4% for the females) when beheaded. Sex ratios were significantly different ($P \leq 0.001$) from 1 : 1 only in the two ponds stocked with the mixture of postlarvae and juveniles and in these cases the females comprised a greater portion of the population (Table 4). As observed in other grow-out trials, female prawns displayed a relatively normal, unimodal size distribution whereas males exhibited a typical multi-modal, skewed distribution (Table 5). Among the females, the distributions of individuals and weights were similar while among the males these distributions were substantially dissimilar (Table 5).

Feed management

Feeding rates were maintained at relatively low levels throughout the growing season, and after the initial four-week period they ranged from 6.0 - 1.0% of estimated biomass/day (Table 6). The back-calculated feeding rates corresponded very closely to the desired feeding levels. Estimates at the mid-point levels (actual feeding rates at the middle of each four-week interval) varied from 4.2 - 1.1% for all treatments, excluding the initial period. Mean feed conversion were 1.71, 2.20 and 2.24 for the postlarvae, postlarvae + juveniles and juveniles alone stocking strategies respectively.

TABLE 3. *Distribution of tail weight for Malaysian prawn reared in ponds under three stocking strategies*

Tail Count[1] (Tails/lb)	Postlarvae			Postlarvae + Juveniles			Juveniles		
	Yield	Distribution		Yield	Distribution		Yield	Distribution	
	(Kg/ha)	(%)	(Σ %)	(Kg/ha)	(%)	(Σ %)	(Kg/ha)	(%)	(Σ %)
>90	24.2	5.9	5.9	25.4	4.5	4.5	22.7	4.0	4.0
81-90	8.2	2.0	7.9	6.0	1.1	5.6	6.7	1.2	5.2
71-80	15.6	3.8	11.7	7.7	1.4	7.0	7.5	1.3	6.5
61-70	46.3	11.3	23.0	16.6	2.9	9.9	15.2	2.6	9.1
56-60	36.0	8.8	31.8	16.7	2.9	12.8	15.1	2.6	11.7
51-55	51.3	12.5	44.3	27.9	4.9	17.6	32.2	5.6	17.3
46-50	56.6	13.8	58.1	51.5	9.0	26.6	65.6	11.4	28.7
41-45	40.2	9.8	67.9	93.0	16.3	42.9	94.6	16.5	45.2
36-40	32.3	7.9	75.7	90.0	15.8	58.7	87.8	15.3	60.5
31-35	34.8	8.5	84.3	57.9	10.2	68.9	58.5	10.2	70.7
26-30	36.3	8.8	93.1	43.8	7.7	76.6	61.6	10.7	81.4
21-25	21.2	5.2	98.3	48.2	8.5	85.1	64.4	11.2	92.6
16-20	7.7	1.9	100.0	71.6	12.6	97.6	38.9	6.8	99.4
11-15	0.0	0.0	100.0	13.8	2.4	100.0	3.4	0.6	100.0
6-10	0.0	0.0	100.0	0.0	0.0	100.0	0.0	0.0	100.0
≥ 5	0.0	0.0	100.0	0.0	0.0	100.0	0.0	0.0	100.0
TOTAL	410.7	—	—	570.1	—	—	574.2	—	—

[1] These tail count categories are employed by National Marine Fisheries Service for reporting landings of penaeid shrimp. They typically represent marketing categories in the U.S.A.

TABLE 4. *Production analysis for Malaysian prawn reared in ponds under various stocking strategies*

	Stocking Strategy								
	Postlarvae			Postlarvae + Juveniles			Juveniles		
	Male	Female	Combined	Male	Female	Combined	Male	Female	Combined
Whole prawn production (kg/ha) ..	451.7	388.6	840.3	623.3	571.4	1203.7	650.7	556.0	1206.7
Tail Weight Production (kg/ha) ..	211.0	199.6	410.6	280.7	289.3	570.0	292.5	281.6	574.1
Tail Weight Yield (%)[1] ..	46.7	51.4	48.9	44.4	50.6	47.3	45.0	50.7	47.6
Mean size (g) ..	19.7	15.8	17.6	26.6	20.2	23.1	25.4	20.2	22.7
Sex Distribution (%) ..	48.3	51.7	—	45.8[2]	54.3[2]	—	48.2	51.8	—

[1] Percent of whole prawn weight i.e. tail weight (with shell).

[2] Statistically significant at $P \leq 0.001$.

Table 5. *Population structure of Malaysian prawn reared in ponds by sex for various stocking strategies. Frequency distribution data are expressed as percents (%) of harvest populations (N or weight)*

Size Class (g)	Distribution of Individuals: Males		Distribution of Individuals: Females		Distribution of Weight: Males		Distribution of Weight: Females	
	% N	Σ % N	% N	Σ % N	% Wt.	Σ % Wt.	% Wt.	Σ % Wt.
Stocking Strategy: Postlarvae								
0- 4.9	11.1	11.1	1.4	1.4	2.2	2.2	0.3	0.3
5.0- 9.9	19.7	30.8	3.2	4.6	7.1	9.3	1.7	2.0
10.0-14.9	11.7	42.5	32.3	36.9	7.3	16.6	27.0	29.0
15.0-19.9	12.5	55.0	52.5	89.4	11.1	27.7	56.5	85.5
20.0-24.9	11.1	66.1	10.0	99.4	12.6	40.3	13.6	99.1
25.0-29.9	11.4	77.5	0.5	99.9	15.9	56.2	0.8	99.9
30.0-34.9	9.6	87.1	0.1	100.0	15.7	71.9	0.2	100.0
35.0-39.9	5.7	92.8			10.8	82.7		
40.0-44.9	3.8	96.6			8.1	90.8		
45.0-49.9	1.7	98.3			4.1	94.9		
50.0-54.9	0.5	98.8			1.4	96.3		
55.0-59.9	0.9	99.7			2.5	98.8		
60.0-64.9	0.2	99.9			0.5	99.3		
≥ 65.0	0.1	100.0			0.7	100.0		
Stocking Strategy: Postlarvae + Juveniles								
0- 4.9	7.7	7.7	1.9	1.9	1.2	1.2	0.3	0.3
5.0- 9.9	21.0	28.7	2.5	4.4	5.8	7.0	0.9	1.2
10.0-14.9	11.0	39.7	6.5	10.9	5.1	12.1	4.3	5.4
15.0-19.9	7.3	47.0	33.1	44.0	4.8	16.9	29.2	34.6
20.0-24.9	8.2	55.2	41.4	85.4	6.9	23.8	45.5	80.1
25.0-29.9	7.2	62.4	12.4	97.8	7.3	31.1	16.4	96.5
30.0-34.9	6.4	68.8	1.8	99.6	7.7	38.8	2.8	99.3
35.0-39.9	6.0	74.8	0.3	99.9	8.4	47.2	0.6	99.9
40.0-44.9	4.5	79.3	0.0	99.9	7.2	54.4	0.0	99.9
45.0-49.9	5.1	84.4	0.1	100.0	8.9	63.3	0.2	100.0
50.0-54.9	4.3	88.7			8.7	72.0		
55.0-59.9	3.4	92.0			7.0	79.0		
60.0-64.9	2.9	94.9			6.8	85.8		
≥ 65.0	5.1	100.0			14.2	100.0		
Stocking Strategy: Juveniles								
0- 4.9	6.1	6.1	1.2	1.2	0.9	0.9	0.2	0.2
5.0- 9.9	20.2	26.3	0.7	1.9	5.8	6.7	0.2	0.4
10.0-14.9	10.7	37.0	4.9	6.8	5.2	11.9	3.3	3.7
15.0-19.9	7.9	44.9	41.6	48.4	5.3	17.2	37.0	40.7
20.0-24.9	7.4	52.3	39.6	88.0	6.5	23.7	43.2	83.9
25.0-29.9	9.9	62.2	10.2	98.2	10.7	34.4	13.4	97.3
30.0-34.9	7.8	70.0	1.6	99.8	10.0	44.4	2.5	99.8
35.0-39.9	7.9	77.9	0.2	100.0	11.7	56.1	0.3	100.0
40.0-44.9	6.9	84.8			11.5	67.6		
45.0-49.9	4.8	89.6			9.0	76.6		
50.0-54.9	4.9	94.5			10.1	86.7		
55.0-59.9	2.9	97.4			6.6	93.3		
60.0-64.9	1.2	98.6			2.8	96.1		
≥ 65.0	1.4	100.0			3.9	100.0		

TABLE 6. *Estimated and back-calculated feed rates (% biomass) for pond-reared Malaysian prawn reared under various stocking strategies*

Period	estimated initial feed rate[1]	Back-calculated feed rates after harvest[2]								
		Post-larvae			Postlarvae + Juveniles			Juveniles		
		Initial	Final	Mid-Point	Initial	Final	Mid-Point	Initial	Final	Mid-Point
1 (wk. 0-4) ..	16.8	17.7	2.5	4.2	17.5	3.3	5.5	20.0	7.5	10.7
2 (wk. 5-8) ..	6.0	6.1	1.2	2.0	5.8	2.7	3.6	4.6	1.9	2.8
3 (wk. 9-12) ..	6.0	6.1	3.3	4.2	6.1	3.8	4.6	6.2	3.9	4.7
4 (wk. 13-16) ..	3.3	3.6	2.0	2.6	3.2	2.2	2.6	3.2	2.4	2.7
5 (wk. 17-20) ..	3.0	3.1	2.2	2.6	2.8	2.2	2.5	3.1	2.1	2.5
6 (wk. 21-22) ..	1.0	1.1	1.2	1.1	1.3	1.3	1.3	1.3	1.3	1.3

[1] Feed rates estimated during growing season. Based on expected growth and survival data.

[2] Feed rates back-calculated using the growth and survival data obtained at time of harvest.

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ECONOMIC COMPARISONS OF STOCKING AND MARKETING STRATEGIES FOR AQUACULTURE OF PRAWN *MACROBRACHIUM ROSENBERGII* (*DE MAN*) IN SOUTH CAROLINA, U.S.A.

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ABSTRACT

During 1978 three stocking strategies (stocking postlarvae, stocking a mixed population of postlarvae and juveniles, and stocking juveniles only) were compared at the same density (64,600 prawns ha^{-1}) for seasonal production of prawns in South Carolina ponds. Following harvest, production costs were estimated for each strategy over a range of prices for seed prawns ($10-50/thousand). Revenues were also estimated for each stocking treatment based on four marketing strategies : (1) substitution for penaeid shrimp at local dock (commercial breader's) prices (tails only) ; (2) substitution for imported *Macrobrachium* (tails only) ; (3) sale as a farm-reared premium product with prawns > 33 g sold heads-on to specialty outlets and the remainder of the crop marketed as a tail product at local penaeid prices ; and (4) sale of large animals whole as in option 3 and the remainder of the crop marketed at imported prawns prices.

In South Carolina, fixed costs for a 6.3 ha prawn farm consisting of ten 0.4 ha ponds were estimated to be $432.62/pond for all strategies. Estimates of variable costs (including feed and processing but excluding seed) were $710.23, $964.48 and $974.09/pond, respectively for the postlarvae only, postlarvae + juveniles, and juveniles only stocking strategies.

Revenue estimates indicated profit potential for the two stocking strategies involving juveniles at seed costs up to $30/thousand. However, this potential is based on the assumption that a specialty market for large whole prawns will be readily accessible to South Carolina growers. Under our cost and revenue assumptions, stocking postlarvae alone appears unlikely to be commercially attractive, unless seed is provided free by government.

INTRODUCTION

POND CULTIVATION of the freshwater prawn, *Macrobrachium rosenbergii* (de Man), has become commercially attractive in many parts of the world, especially in warmer climates where the prawns can be grown all year (Hanson and Goodwin, 1977). In such areas, grow-out ponds are maintained in a more or less continuous production cycle, and all prawns harvested are of a similar large size. In contrast, the growing season is restricted and discontinuous in temperate areas such as South Carolina since winter water temperatures are lethal to the prawns. In such areas prawns are batch-harvested by pond drainage following a relatively short growing period (5-7 months). Total production and mean prawn size at harvest are, thus, less than those obtained from continuous production ponds, and the crop includes a broad

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range of prawn sizes. Despite these limitations, seasonal production of prawns appears to have potential as an agricultural alternative in areas such as South Carolina (Roberts and Bauer, 1978 a, b ; Smith *et al.*, 1978).

During 1978 three stocking strategies (stocking postlarvae, stocking a mixed population of postlarvae and juveniles, and stocking juveniles only) were compared at the same density (64,600 animals ha^{-1}) for seasonal production of prawns in South Carolina ponds (Smith and Sandifer, 1981). Following harvest, production costs were estimated for each strategy over a range of prices for seed prawns and potential revenues were computed for different marketing options. The present paper compares estimated costs and revenues associated with the three stocking strategies. However, it is not intended as a detailed economic feasibility analysis.

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MATERIALS AND METHODS

Roberts and Bauer (1978 a, b) developed a financial budget for small-scale farming of *Macrobrachium* prawns as an alternative agricultural crop option in coastal South Carolina. The crop budget was prepared assuming a hypothetical production unit of ten 0.405 ha ponds of the type described by Smith *et al.* (1976). These ponds are rectangular, have a sloped bottom, and are equipped with concrete harvest basins and corrugated metal drainage structures. The present economic comparison of the three stocking strategies tested by Smith and Sandifer (1981) is based on the budget generated by Roberts and Bauer (1978 a, b), with appropriate changes as necessary. All estimated costs and revenues are presented on a per pond (0.405 ha) basis for a hypothetical 10-pond farm. It is assumed that most costs (*e.g.*, for construction, equipment, repair and maintenance, etc.) have increased by 20% since Roberts and Bauer (1978 a, b) did their calculations. It is further assumed that prawn farming will be carried on in conjunction with other farming operations. Stocking and production data for the three stocking strategies are presented by Smith and Sandifer (1981) and summarized in Table 1.

Total revenues were estimated for each stocking treatment based on four marketing strategies : (1) substitution for penaeid shrimp at local dock (commercial breader's) prices (tails only product) ; (2) substitution for imported *Macrobrachium* (tails only product) ; (3) sale as a farm-reared premium product with prawns > 33 g sold heads-on to speciality outlets and the remainder of the crop marketed as a tail product at local penaeid prices ; and (4) sale of large animals whole as in option 3 and the remainder of the crop marketed at imported prawn prices. Prawns to be marketed whole would be processed by having the appendages trimmed, resulting in a weight loss of ~ 7%. This loss was taken into account in calculating revenues. Market prices representative of harvest time (early fall) are listed in Table 2 for each of the market options.

COST ANALYSIS

Estimated production costs are summarized in Tables 3 and 4 and explained in detail below.

Variable costs

Electricity : The cost of electricity is calculated using a rate of $0.044/kwh. It is

TABLE 1. *Mean stocking and production data for* Macrobrachium rosenbergii *reared under three stocking strategies in ponds in South Carolina (from Smith and Sandifer, 1981)*

	Stocking	Harvest			
Stocking Strategy	Mean Size (g)	Mean Size (g)	Survival (%)	Production kg/pond[1]	Food Conversion
Postlarvae ..	0.09	17.7	72.4	340.3	1.71
Postlarvae + Juveniles ..	0.65	23.1	70.9	487.6	2.20
Juveniles ..	0.51	22.7	77.4	488.8	2.24

[1]Pond — 0.405 ha.

TABLE 2. *Representative prices for prawns sold under different marketing strategies*

Size category (no./kg)	Prices ($/kg)	
Whole prawns[1]	Institutional[2]	
< 18	9.90	
18-22	8.80	
23-33	7.70	
Tails only[1]	Local penaeid[3]	Imported prawn[4]
24-33	13.75	10.45
34-44	12.65	10.12
45-55	11.44	8.80
56-66	10.56	8.58
67-77	9.68	7.59
78-88	7.92	7.04
89-99	7.26	6.27
100-110	6.82	6.27
111-121	5.94	5.50
122-132	5.28	5.50
133-154	4.40	4.40
155-176	3.74	2.75
176+	2.42	1.65

[1] Approximate metric equivalents of size classes (no./lb) representing typical marketing categories in the U.S.A

[2] Approximate, based on prices reportedly received by farms marketing in Florida, Hawaii and Puerto Rico.

[3] Price estimates obtained from the Office of Conservation, Management and Marketing, South Carolina Wildlife and Marine Resources Department, for mid-October 1979.

[4] Price data from Fishery Market News Report, N-93, 2 Aug. 1979 (U.S. Dept. Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service) with our estimates for prices missing from report,

assumed that a 20 hp electric pump with a capacity of 2.65 m^3/min (159 m^3/h) is used to fill the ponds, flush them as necessary to remove undesirable algae or improve water quality, and maintain water level (Roberts and Bauer, 1978 a, b). By definition, one hp=0.746 kw; therefore, the pump would require 14.92 kw of electricity/h to operate.

The volume of water required to fill each pond initially is 4,715 m^3 (0.41 ha pond × 1.15 m average depth). Cost to fill = 4715 m^3 ÷ 159 m^3/h × 14.92 kw × \$0.044/kwh = \$19.47 (excluding frictional losses).

Evaporation loss (*i.e.*, evaporation — rainfall) is estimated to be 0.131 m during the growing season in South Carolina (Roberts and Bauer, 1978 a, b). Seepage is arbitrarily assumed to be twice the evaporative loss, although it is highly site specific. Replacement cost = 0.131 m × 3 × 4,050 m^2/pond ÷ 159 m^3/h × 14.92 kw × \$0.044/kwh = \$6.57. Water requirements for flushing are estimated at 25% of filling needs, \$4.87.

One 1/3 hp floating mechanical aerator is maintained for each two ponds. Maximum aeration needs are projected to be 8 h/day for 110 days of the growing season. However, in field experiments, actual aeration needs were much lower. Cost to aerate = 1/3 hp × 0.746 kw/hp × 8 h/day × 110 days × \$0.044/kwh = \$9.63.

TABLE 3. *Summary of estimated average cost for seasonal production of prawns in ponds in South Carolina (based on production results of Smith and Sandifer, 1981)*

Item	Cost (\$/Pond)	Percent of total Cost
Variable costs		
Electricity (921.1 kwh, \$0.044/kwh)	40.54	2.0
Labour (\$63.6 h, \$3.25/h)	206.70	10.4
Fertilizer (46.4 kg, \$0.12/kg)	5.57	0.3
Repair and maintenance	66.00	3.3
Seed (\$0-50/thousand, assume \$25/thousand)	655.00	33.0
Feed (\$234.53-441.21, average = \$369.34)	369.34	18.6
Processing (\$119.11-171.08, average = \$153.62)	153.62	7.7
Miscellaneous	24.00	1.2
Interest on operating capital (1/2 of \$1,520.77 at 9.5% for 5 mos.)	30.10	1.5
Total	\$1,550.87	78.0
Fixed costs		
Interest on pond investment (10% of \$18,416 over 10 ponds)	184.16	9.3
Depreciation		
Harvest basin and drain (\$636, 12 γ life)	52.98	2.7
Pump and assembly (\$2,978, 12 γ life, 10 ponds)	24.81	1.3
Distribution pipe (\$188.64, 12 γ life)	15.71	0.8
Aerator (\$420/2 ponds, 5 γ life)	42.00	2.1
Feeder and storage (\$2568, 10 γ life, 10 ponds)	25.68	1.3
Truck (\$9,000, 15%, 6 γ life, 10 ponds)	22.55	1.1
Boat (\$400, 10 γ life, 10 ponds)	4.00	0.2
Instruments (\$612, 5 γ life, 10 ponds)	12.24	0.6
Seine (\$480, 5 γ life, 10 ponds)	9.60	0.5
Land charge (\$61.73/ha/γ, 6.3 ha, 10 ponds)	38.89	2.0
Total	\$ 432.62	21.9
Total average costs	\$1,983.49	99.9

Total cost for electricity during the growing season is estimated to be $40.54/pond.

Labour: Roberts and Bauer (1978 a, b) estimated that a total of 54.1 h of labour would be required per pond during the growing season. We have revised these estimates slightly as follows, based on our experiences during the 1978 growing season. We assume a labour cost of $3.25/h.

Task	*h/pond/ season*	*Cost* ($)
Stocking ..	2.0	6.50
Water quality analyses	13.0	42.25
Feeding ..	24.5	79.62
Aeration and management ..	4.5	14.63
Pond and equipment maintenance ..	3.6	11.70
Harvesting, washing and transporting crop ..	16.0	52.00
	63.6	206.70

Fertilizer: Actual use of 10-10-10 fertilizer during the 1978 growing season averaged 46.4 kg/pond. The current (mid-1979) farm cost for such fertilizer is $0.12/kg.

Fertilizer cost = 46.4 kg × $0.12/kg = $5.57.

Repair and maintenance: Roberts and Bauer (1978 a, b) estimated these costs at $55.00 season. We have used their estimate, adjusted for increased labour and material costs: $66.00.

Seed stock: Roberts and Bauer (1978 a, b) assumed that seed would be provided free or at low cost by a State-owned hatchery, and thus did not include seed costs in their budget. They based their assumption on the situation in Hawaii where a State hatchery supplies co-operating prawn farmers with postlarvae at no cost for the first three years of operation and at the variable cost of production thereafter (*e.g.*, $6/thousand, Shang and Fujimura, 1977; $10/thousand, Gibson and Wang, 1977). While there remains some possibility that a government hatchery might provide seed prawns for farmers in South Carolina, it appears more likely that farmers here and in other southeastern states will have to purchase seed from commercial suppliers. Recently advertised prices for postlarvae range from $25-50/thousand, with discounts for large quantity purchases. Little information is currently available concerning possible prices for larger, nursery-reared juveniles. For the present comparison, we have considered a broad range of prices ($0-50/thousand) to elucidate the impact of different levels of seed stock costs on the potential profitability of each of the three stocking strategies. All costs were computed for the same stocking density, 26,200 prawns/pond.

Range of seed prices ($/Thousand)	*Range of seed Costs ($/Pond)*
0 (free from government hatchery)	0
10	262.00
20	524.00
30	786.00
40	1,048.00
50	1,310.00

Feed: Actual mean production levels and feed conversions (FC) (*i.e.*, kg dry food to produce 1 kg live prawns) obtained during the 1978 rearing experiment were used to estimate feed costs (Table 1). Cost of the feed (Ralston Purina Marine Ration 25) was $0.403/kg delivered.

Feed cost = kg prawns/pond × FC × $0.403/kg food = $234.53 for postlarvae strategy, $432.29 for postlarvae + juveniles strategy, and $441.21 for juveniles only strategy, *Processing*: Processing costs were not included by Roberts and Bauer (1978 a, b). For the present analysis, a local cost of \$0.35/kg for grading, heading, icing and packaging penaeid shrimp was charged. This resulted in processing cost estimates of \$119.11, \$170.66 and \$171.08/pond, respectively for the postlarvae, postlarvae + juveniles and juveniles only stocking strategies.

Interest costs = \$13.78 - 39.71/pond for postlarvae strategy;

= \$18.72 - 44.65/pond for postlarvae + juveniles strategy;

= \$18.90 - 44.83 / pond for juveniles only strategy.

TABLE 4. *Total estimated costs (\$/0.405 ha pond) of producing prawns in South Carolina for different stocking strategies and seed costs*

Stocking strategy	Seed cost (\$/Thousand) 0	10	20	30	40	50
Postlarve only						
Variable	710.23	977.42	1,244.60	1,511.79	1,779.08	2,046.16
Fixed	432.62	432.62	432.62	432.62	432.62	432.62
Total	1,142.85	1,410.04	1,677.22	1,944.41	2,211.70	2,478.78
Postlarvae + Juveniles						
Variable	964.48	1,231.66	1,498.85	1,766.02	2,033.22	2,300.41
Fixed	432.62	432.62	432.62	432.62	432.62	432.62
Total	1,397.10	1,664.28	1,931.47	2,198.64	2,465.84	2,733.03
Juveniles only						
Variable	974.00	1,241.19	1,508.37	1,775.56	2,042.74	2,309.93
Fixed	432.62	432.62	432.62	432.62	432.62	432.62
Total	1,406.62	1,673.81	1,940.99	2,208.18	2,475.36	2,742.55

Miscellaneous: Roberts and Bauer (1978 a, b) estimated miscellaneous costs at \$20.00/pond/season. We have used the same estimate here, adjusted for inflation: \$24.00.

Interest on operating capital

Roberts and Bauer (1978 a, b) computed interest on operating capital as the product of ½ the total operating costs and an annual interest rate of 9% for six months. We followed the same approach, but adjusted the interest rate to 9.5% and the time period to five months. Interest rates were calculated at every level of seed costs, but only the ranges are given below.

Fixed costs

Pond construction and levee stabilization: The total cost of building levees of excavated soil, surfacing the levees with limestone, and planting the slopes is estimated to be \$18,416.00, adjusted for inflation, for a 10-pond production unit (Roberts and Bauer, 1978 a, b). Annual fixed cost for pond construction is calculated using 10% as representative of alternative investments.

Construction cost = \$18,416 ÷ 10 ponds × 0.1/y = \$184.16.

Depreciable costs: Cost estimates for harvest basins and drains, pump assembly, water distribution pipe, aerators, feed and feed storage, boat, water quality instruments, and seine were taken from Roberts and Bauer (1978 a, b) and adjusted for inflation. Cost estimates for these items are listed in Table 3 and total $187.02/pond.

No estimate of vehicle cost was included by Roberts and Bauer (1978 a, b). Here we assume that one pick-up truck costing $9,000 and with a useful life of 6 yr would be needed 15% of the time for the 10-pond production unit. We further assume that the other 85% of truck cost would be charged against other farming operations.

Truck cost = $9,000.00 × 0.15 × 0.167/y ÷ 10 ponds = $22.55.

Land charge: Roberts and Bauer (1978 a, b) did not include any cost for land. We assume that prawns will be considered simply as an alternative agricultural crop. Currently, agricultural land in South Carolina is charged at the rate of $61.73/ha/y in crop budgets. We estimate that our hypothetical farm of ten 0.405 ha ponds would require a total of 6.3 ha of land, including access road, levees, etc.

Land cost = $61.73/ha/y × 6.3/ha ÷ 10 ponds = $38.89.

REVENUES

Estimates of gross revenues for the prawn crops ranged from $994.57-$2,526.86/pond, depending on stocking and marketing strategies (Table 5). Overall, the two stocking strategies involving juvenile prawns produced similar revenue estimates, despite significant differences in their initial population structures. Further, estimates of revenues from these ponds ranged from ~ 62-96% greater than those generated by the postlarvae—only ponds, depending on market strategy.

TABLE 5. *Estimates of potential gross revenues ($/0.405 ha pond) for prawn crops produced and sold under different stocking and marketing strategies*

Market strategy		Stocking strategy: Postlarvae	Postlarvae + Juveniles	Juveniles
Tails only product				
Penaeid[1]	..	1,146.26	1,960.49	1,928.21
Imported prawn[2]	..	994.57	1,635.98	1,615.49
Whole + tails product				
Whole + penaeid[3]	..	1,323.74	2,346.02	2,526.86
Whole + prawn[4]	..	1,251.39	2,273.46	2,452.38

[1] Based on local prices for penaeid shrimp, Oct. 1979. Price data from Office of Conservation, Management and Marketing, South Carolina Wildlife and Marine Resources Department.

[2] Based on prices from Fishery Market News Report, N-93, 2 Aug. 1979 (U.S. Dept. Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service).

[3] Based on prices received for whole prawns in Florida, Hawaii and Puerto Rico and local prices for penaeid shrimp tails.

[4] Based on prices received for whole prawns in Florida, Hawaii and Puerto Rico and prices for imported prawn tails.

As expected, the diversified marketing strategy in which large prawns would be sold as a speciality whole product and the remainder of the crop as substitutes for penaeid shrimp tails generated the greatest revenues (Table 5). This strategy would produce revenues ~ 16 20 and 31% greater than those resulting from sale of the entire crop as a substitute for penaeid tails for the postlarvae, postlarvae + juveniles and juveniles only stocking strategies, respectively. Even greater percentage increases in revenue (~26, 39 and 52%, respectively) would be realized by selling the large animals whole if the tails-only product is considered only equivalent to imported prawns.

If the large prawns are marketed as a whole speciality product, estimates of net revenues indicate a reasonable profit potential for the two stocking strategies involving juveniles at seed costs upto $30/thousand (Table 6). A near break-even situation appears likely for the juveniles only sra tegy at seed costs upto $40/thousand. If prawns from these stocking

TABLE 6. *Comparison of potential net revenue ($/0.405 ha pond) for prawn crops produced under different stocking strategies as a function of seed cost and market strategy (numbers in parentheses are negative returns)*

Stocking strategy/ Seed cost ($/1000)	Marketing strategy: Tails only — Penaeid[1]	Tails only — Imported prawn[2]	Whole + tails — Penaeid[3]	Whole + tails — Prawn[4]
Stocking strategy: Postlarvae only				
0	(3.41)	(148.28)	180.89	108.44
10	(263.78)	(415.47)	(86.30)	(158.65)
20	(530.96)	(682.65)	(353.48)	(425.83)
30	(798.15)	(949.84)	(620.67)	(693.02)
40	(1065.44)	(1217.13)	(887.96)	(960.31)
50	(1332.52)	(1484.21)	(1155.04)	(1227.40)
Stocking strategy: Postlarvae + Juveniles				
0	563.39	238.88	948.92	876.36
10	296.21	(28.30)	681.74	609.18
20	29.02	(259.49)	414.55	341.99
30	(238.16)	(562.67)	147.37	74.82
40	(505.35)	(829.86)	(119.82)	(192.38)
50	(772.54)	(1097.05)	(387.01)	(459.57)
Stocking strategy: Juveniles only				
0	521.59	209.87	1120.24	1045.76
10	254.40	(58.32)	853.05	778.57
20	(12.78)	(325.50)	585.87	511.39
30	(279.97)	(592.69)	318.68	244.20
40	(547.15)	(859.87)	51.50	(22.89)
50	(814.34)	(1127.06)	(215.69)	(290.17)

[1] Based on local prices for penaeid shrimp, Oct. 1979. Price data from Office of Conservation, Management and Marketing, South Carolina Wildlife and Marine Resources Department.

[2] Based on prices from Fishery Market News Report, N-93, 2 Aug. 1979 (U.S. Dept. Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service).

[3] Based on prices received for whole prawns in Florida, Hawaii and Puerto Rico and local prices for penaeid shrimp tails.

[4] Based on prices received for whole prawns in Florida, Hawaii and Puerto Rico and prices for imported prawn tails.

strategies are marketed entirely as a tails-only product at local prices for penaeid shrimp, a profit or break-even situation is likely to be realized only at seed costs ≤$20/thousand. The postlarvae only stocking strategy showed little profitpotential under our cost and revenue assumptions, unless seed is availble at no cost to the farmer.

Discussion

Based on the preceding analysis, seasonal farming of freshwater prawns as an agricultural option in South Carolina is much more likely to be profitable for stocking strategies involving juvenile prawns than if newly metamorphosed postlarvae alone are stocked. In fact, under our cost and revenue assumptions, stocking postlarvae alone appears unlikely to be commercially attractive, unless seed is provided free by government. More likely, farmers will have to purchase seed from private suppliers.

For the juveniles only and mixed stocking strategies, results of our economic comparisons indicate a significant profit potential at seed costs upto $30/thousand. This seed cost level is probably a little low, considering that both postlarval and juvenile seed are involved. However, no data are yet available on the cost of producing larger seed, but obviously they will be more expensive than postlarvae. Further, these results are predicated on the assumption that a speciality market for large whole prawns will be readily accessible to South Carolina growers. If instead the prawns must be marketed as shrimp tails only, South Carolina growers could afford much less for seed.

Of the costs included in our crop budgets, that for seed was the most significant (Table 3). Each $10/thousand increase in the price of seed increased total cost by 23% over base (*i.e.*, total costs excluding seed) for the postlarvae only strategy and 19% for each strategy involving juveniles. Thus, anything that would reduce seed costs would increase profits substantially. For example, if stocking density could be decreased appreciably without a major reduction in crop value (*i.e.*, produce a somewhat smaller biomass but with a greater proportion of larger, more valuable prawns), profitability might be improved. We are testing this idea currently. Also, recent competition among private suppliers has already forced seed prices down somewhat from the previous general level of $50/thousand, and continued competition may result in further price reductions.

The second greatest cost in our budget was for feed. Obviously, improvements in feed conversions over those seen here (1.7-2.2 : 1) could result in significant savings. Based on data from a 1979 study (Sandifer and Smith, unpublished) and results reported by Willis and Berrigan (1977) from Florida, we believe that feed conversions on the order of 1 : 1 are quite possible on a well-managed prawn farm. Such an improvement in feed utilization might result in as much as a 10% decrease in total cost of production and thus an increase in profits.

While we do not yet advocate investment in seasonal prawn culture in South Carolina and other areas of mild temperate climate, such culture clearly appears to have commercial potential as a part of ongoing agricultural enterprises. However, we emphasize that this apparent potential rests on many assumptions, perhaps the most important of which are that small growers would have ready access to speciality markets for whole prawns and that seed costs for juveniles or a mixture of postlarvae and juveniles would not exceed $30/thousand. As yet, neither of these assumptions has been demonstrated.

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SOME CONSTRAINTS IN PRAWN CULTURE

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ABSTRACT

During recent years prawn culture has become very popular especially for increasing resources for the export market. Many new entrepreneurs have come into the field following conventional methods or practices based on information received from concerned institutes. In many cases prawn culture has proved to be profitable, but the constrains are many and in some cases serious losses have occurred. At this juncture it is desirable to review the various aspects of prawn culture so as to find out methods to overcome the difficulties experienced by the farmer. The major difficulties met with are (1) Preparation of ponds and their maintenance ; (2) Exclusion of predators from the culture pond ; (3) Collection and transportation of suitable fry for stocking ; (4) Lack of sufficient knowledge regarding the optimum number to be stocked in a particular type of pond ; (5) Feeding and location of cheap food ; (6) Diseases of prawn cultured in captivity especially softening of shell and diseases caused by bacteria and fungi which result in mass mortality ; and (7) Changes in the hydrographical conditions of the pond particularly as a result of monsoon rains. Based on the studies carried out in Kerala the various limiting factors in prawn culture are discussed.

INTRODUCTION

DURING the last few years prawn culture has become popular especially for increasing production for the export market. In many cases prawn culture has proved to be profitable, but the constraints are many and in some cases serious losses have occurred. Some of the major difficulties met with by the farmer are discussed here.

CONSTRAINTS IN PRAWN CULTURE

Preparation of ponds and maintenance of bunds

Though some species of prawns such as *Macrobrachium rosenbergii*, *M. malcomsonii* and *M. rude* could be cultured in freshwater ponds, the brackishwater ponds are more suitable for prawn culture particularly for penaeid prawns. Though different sizes of ponds are in vogue for prawn culture the minimum size should be 10 x 10 x 0.75 m. Shallower ponds are not suitable as temperature in such ponds may rise up during summer. Deeper ponds are advantageous though it would be difficult to keep them in fertile condition. However in deeper ponds poly-culture would be feasible and fishes like mullets and *Chanos* could also be introduced advantageously. The larger the pond the better the yield could be though management will be more difficult. The ponds may have earthern walls, preferably reinforced with stones or concrete especially in regions where wave action or flood is likely to destroy the bunds. Growing of suitable turf, grass or shrubs on the bunds often help to keep them in position. The bunds should be of sufficient height so that tidal or flood waters do not overflow into the ponds. Though pure muddy bottom is not suitable, bottom with sandy mud or muddy sand is found to be more fertile and would serve as better substratum for benthos which would form food of prawns. A comparatively hard bottom with only a few mm of loose sediment on the surface is recommended. The ponds have to be provided with adjustable sluices and gratings for the free flow of water. Gratings with fine meshes prevent the escape of prawns stocked and prevent the entrance of predators into the pond. Though nylon netting is good, they somtimes get damaged by the attack of crabs. Gratings made of bamboo pieces or wire mesh are sometimes used. Though wire mesh is stable, it gets damaged by rusting in salt-water. By occasional checking and replacing spoiled ones metal mesh gratings are found to be the best. Double gratings could be provided for more safety.

The maintenance of bunds is a problem, varying in different localities. Rains, floods and waves may damage the bunds depending on their forms. Crabs often cause severe damage to the bunds which results in the escape of prawns and admission of predators from outside. The mud lobster *Thalassina* sp. which burrows in the bunds weaken them, causing leakage. The crabs and mud lobster may be killed by pouring qucik lime into the holes in the bunds. Burrows made by rats also cause destruction to the bunds. This could be prevented only by constant checking of the bunds and carrying out repairs.

Exclusion of predators from culture ponds

After construction of pond, the usual practice is to pump out water or kill all organisms in the pond by applying some poisons whose residual effect will be for only a short period. Tea seed cake or 'mahua' is commonly used. This will exterminate all predators and the pond will be suitable for stocking after two weeks. It is also desirable to keep the pond in dry condition for sometime if it is practicable. In ponds which are not fertile organic manures like cow-dung or inorganic manures such as phosphates and nitrates could be applied, which would help in the blooming of algae and thus enriching the water with phyto-zooplankton and benthos.

The larvae of predators, including perches and crustaceans may get into the ponds through the meshes of gratings and get themselves established. Perches are found to devour even large prawns. However, no satisfactory method is yet available for the complete eradication of these pests from the ponds. Constant checking and removing them may be helpful in small ponds.

Collection and transportation of prawn fry

Recent investigations have shown that fry of some of the commercial species of prawn such as *P. indicus*, *M. dobsoni*, *M. monoceros* and *P. monodon* are available in various localities both in the coastal waters and shallow regions of estuaries. It has been observed that 2,000 to 5,000 prawn fry could be collected per day by a single person from some of the shallow creeks of the estuaries during fair pre-monsoon season. But, the major difficulty is the identification of fast growing species in the field. Among the marine prawns, *P. monodon* is the most profitable for prawn culture as it has maximum growth rate of *ca* 30 mm/month and reaches 223 mm size in 9 months. But *P. monodon* is a rare species, especially in Kerala which is the most prominent state engaged in prawn culture. Transportation of *P. monodon* fry from other states has been tried and cultured in some of the farms in Kerala. The growth rate and the maximum size reached by a few common prawns suitable for culture are given in Table 1.

Stocking the prawn seed prior to transportation to fish farms is the next hurdle. Plastic pools of various sizes are now in use, but keeping large number of fry and fingerlings in an enclosed pool results in much mortality ranging from 20-60. Constant aeration, removal of dead fry, replenishing of water and keeping fry in the collection ground itself in suitable enclosures help to reduce mortality.

The fry are not always available in the estuary in considerable numbers and so collection of fry from the estuaries and inshore waters is not a satisfactory method for the supply to the culture ponds. The alternative is the production of seed in hatcheries. Some work has been done in this direction but the technology for mass production for stocking purposes has yet to be developed. The present practice is to collect spawners from commercial catches from the sea and keep them under laboratory conditions and these are found to breed within 12 to 48 hours.

Transportation of prawn seed is another constraint in prawn culture. Kurata and Shigueno (1979) observe that 700,000 seedlings of *P. japonicus* could be transported by truck for 12 hours in a plastic container of 1 ton capacity, equipped with an aeration system. The optimum number of seed of indigenous species that could be transported by various means have to be worked out. Acclimatisation of larvae to the new surroundings would be necessary as it has been observed that maximum mortality of larvae in the stocking pond occurs during the first 24 hours of introduction.

TABLE 1. *Growth rate and maximum size reached by some common prawns suitable for culture*

Species	Growth rate/ month (mm)	Maximum length recorded (mm)
Penaeus monodon Fabricius ..	30	320
P. indicus Milne Edwards ..	20	230
Metapenaeus dobsoni (Miers) ..	10.5	188
M. monoceros (Fabricus) ..	15	180
M. affinis (Milne Edwards) ..	22	180
Macrobrachium rosenbergii (de Man) ..	30	320
M. malcomsonii (Milne Edwards) ..	10	230

In *P. monodon* gonadal development has been induced using eye-stalk ablation techniques on sexually mature females (Santiago Jr., 1977). Continuous aeration of the water is necessary and the greatest difficulty experienced is the feeding of the newly hatched larvae. Diatom cultures (*Skeletonema*) have been helpful, but procurement of sufficient quantity when the prawn larvae are hatched is a problem. Finally ground prawns have been found to be a successful feed, though pollution by remnants is a problem. This could be prevented by constant removal of excess feed. Transferring the larvae to nursery ponds would be advantageous for minimising mortality. After 3 or 4 weeks in the nursery they may be transferred to culture ponds. The larvae collected from the wild could be transferred direct to culture ponds having similar salinity and temperature structure.

Stocking of ponds

In prawn culture our experiments in small ponds and cages have shown promising results, but in large areas the results are not encouraging. Experiments conducted in USA have shown that prawns yielded about 3 tonnes/ha in less than 10 ha ponds.

It is necessary to ascertain the maximum number of seed that has to be stocked in a particular pond. In Japan 15,000 to 30,000 prawn larvae/ha have been cultured and it is found that the introduction of the above numbers in two consignments is more advantageous for getting better yield. The survival rate is usually high when 10 mm and above larvae are stocked. However, the optimum number of prawn larvae to be stocked in a particular pond has to be determined after a thorough study of the ecology of the pond and also taking into account the natural food available and also the amount of artificial feed. But stocking more than $100/m^2$ is a waste of shrimp fry (Kurata and Shigueno, 1979).

Feeding in culture ponds

In most of the prawn culture operations carried out in India feeding is not done. The natural fertility of the pond and the incoming tidal flow provide the food required provided the stocking is not intense. But, if stocking is done on a large scale supplementary feeding is essential. Increasing the fertility of the water by adding cow-dung is an age-old and successful practice, which is comparatively cheap. Though in captivity the prawns feed on various types of food such as rice bran, oil cake, fish waste etc., artificial feed could be prepared using waste materials such as fish offals, prawn shells, green plants, etc. Often such a mixture is enriched with vitamins. Two to three times body weight is the standard daily ration.

Diseases of prawns

The penaeid as well as palaemonid prawns caught in natural surroundings are normally healthy and only rare instances of serious diseases are met with. But in culture ponds especially for those without adequate circulation of water a variety of problems have been encountered. Besides diseases caused by bacteria and fungi, 'thinning' of the exoskeleton has been observed. The reasons for the 'thinning' of the shell other than by moulting have not been fully understood and as such remedies are also not available. This may be due to metabolic changes owing to changes in the ecosystem, probably due to the lack of sufficient available calcium in the water. It has been observed that the life of prawns after 'thinning' is short and there is not much demand for such prawns. Leaching of pesticides and pollutants into the ponds also may result in mass mortality and this would be assessed by constant testing of the water and suitable preventive measures have to be taken.

Changes in the hydrographical conditions of the culture pond

The essential hydrographical factors which affect the growth and survival of prawns are temperature, salinity, pH and dissolved oxygen. Though the prawn could tolerate gradual changes of the above to resonable limit, any sudden change may result in mass mortality.

The normal temperature required for brackishwater farms is 25° to 32°C. Though the prawns could be acclimatised to tolerate lower temperature, the optimum growth is found to be in the above range. However, when dealing with larvae, it is essential that the temperature is kept constant for lessening the percentage of mortality.

As regards salinity, under laboratory conditions *P. indicus*, *M. dobsoni* and *M. monoceros* have been found to tolerate a salinity range between 3‰ and 43‰, but the maximum growth rate occurred in 25 - 30‰S. However, sudden change of salinity during monsoon rains killed the prawns, this being more evident in the ponds separated from the estuary. For fresh water prawns such as *Macrobrachium rosenbergii* low salinity is enough, the best growth being observed in 2 - 4‰ S.

The normal pH of the estuarine and inshore waters will be around 8. Soil acidity as low as 3 - 5 may be caused in the estuarine regions by the decomposition of mangrove roots under anaerobic conditions and accumulation of iron sulphide salts. The coastal alluvia consisting of heavy clay are generally highly acidic. This is mainly, due to the accumulation of iron sulphide in the subsoil. This substance has to be removed for making the pond productive.

The soil acidity can be corrected by the addition of lime and removal of acidity by leaching with the help of tidal flow. Instances have been reported about the sudden lowering of pH in ponds during the first monsoon rains. This may be either due to the leaching of salts from the bunds of newly constructed ponds or by percolation of acidic water from nearby areas. These have to be investigated and acidity corrected.

At normal conditions depletion of oxygen in the ponds may not occur, as the phytoplankton bloom produces enough oxygen during day time. But the presence of too much vegetation and limited tidal flow and rise of temperature on wind-less days may result in oxygen depletion and thereby mass mortality of prawns. A major part of the dissolved oxygen in the pond water is consumed by micro-organisms and suspended organics which may amount to about 75% and only the remaining will be available to the prawns. The oxygen requirement of the prawns varies with species and size. *P. indicus* has been found to tolerate as low as 1.49/ml O_2/1.

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EXPERIMENTAL PRAWN CULTURE IN COASTAL PONDS AT MANDAPAM CAMP

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ABSTRACT

This paper deals with the experimental culture of *Penaeus indicus* and *P. semisulcatus* carried out in two coastal ponds at the fish farm of the Central Marine Fisheries Research Institute at Mandapam Camp for a period of 158 days during 1978 and 1979. Sea water was pumped into the culture pond daily to maintain water level at 0.75 m. Two experiments were carried out to study the growth rate of *P. indicus* at a stocking rate of five numbers per sq. m, one with supplementary food and the other with natural food elements produced by application of inorganic fertilisers. In the third experiment, *P. semisulcatus* stocked at the rate of three per sq. m were fed with pelletised supplementary food. Results of the above experiments are presented and discussed in the background of experimental culture operations carried out earlier.

INTRODUCTION

INCREASING interest is being shown at present for marine prawn farming operations in India owing to the export potential of prawns. Among the two methods of prawn cultivation in vogue, the extensive method has been practiced in India and south-east Asian countries involving natural stocking of prawns in tidal enclosures. The simplest form of semi-intensive prawn culture is practiced in Philippines by stocking *Penaeus monodon* post-larvae collected from estuaries in brackish water ponds, and in India, *P. indicus* and *P. monodon* are selectively stocked in salt pans at Manakkudy and Kakinada (Muthu, 1978). There are plenty of estuarine, coastal lagoon and brackish water area along south-east coast of India, which have not been put into proper utilisation for aquaculture practices (CMFRI, 1978 a). Earlier attempt to study the effective utilisation of a part of the saline lagoon on the Palk Bay coast near Mandapam Camp was carried out by Tampi (1960) by culturing the milkfish, *Chanos Chanos*. In the present report the results on the experimental culture of *P. indicus* Milne Edw. and *P. semisulcatus* de Haan undertaken during 1978-79 in two coastal ponds in the same locality are reported.

The author expresses his grateful thanks to Dr. E. G. Silas, Director, C.M.F.R. Institute and Dr. P. Vedavyasa Rao, Senior Scientist for their keen interest, help and guidance in this work. I am thankful to Mr. P. Bensam, Scientist for going through the paper and for offering suggestions.

CULTURE PONDS

Tampi (1960) gave an account of general outlay of experimental ponds of CMFRI fish farm site along Palk Bay at Mandapam Camp. After the publication of the account by Tampi (1960) a cyclone had hit the farm area in 1964 and the ponds and sluices were partly damaged. In view of this, experimental culture operations were suspended, pending repair of the ponds. Subsequently in February, 1978 one of the culture ponds, previously named as VII by Tampi (1960) was excavated to one metre depth and the damaged bunds were strengthened for using it for prawn culture. In November, 1978, once again due to cyclone, tidal water entered the pond area and damaged the bunds. In February, 1979 one more pond was added in the site for prawn culture operations. Both these ponds were further deepened to a depth of 1 m and the bunds were strengthened by ramming up the earth. The former pond was 30 m long and 15 m wide, with a water area of 450 sq. m, and the latter pond was 28.0 m long and 14.5 m wide, with a water area of 406 sq.m.

The bottom soil of the ponds was admixture of sand and clay with shell fragments of marine molluscs. The soil condition of the lagoon area and the chemical nature of the lagoon mud have been dealt with by Tampi (1959) and Pillai (1954; 1956). As the sluice system was damaged completely, sea water supply to the pond was effected by pumping with the aid of a diesel engine of 6.5 H.P. capacity. The pumped water was filtered through a mosquito net in order to prevent the entry of unwanted organisms such as fish fry. Due to seepage and evaporation, about 25% of the water level went down per day in the ponds and hence sea water was pumped every day during day time and the water level in the ponds was maintained around 0.75 m.

Recording of environmental parameters such as salinity, temperature and dissolved oxygen of the water in the ponds were taken regularly. It was found during the progress of the experiments that surface water temperature did not show significant differences from one pond to another. The values ranged from 30° C to 32°C during April-May period of 1978 and 1979 and in June -September period temperature values varied from 29°C to 31°C. The average monthly salinity and oxygen values are presented in Table 1.

SEED COLLECTION

A good fishery for *P. semisulcatus* is existing off Mandapam (Nandakumar, MS) and the seeds of this commercially valuable prawn are available during March-April and September-October periods in coastal waters of Palk Bay at Thonithurai particularly in the algal bed and at Devipattinam. Eventhough *P. indicus* does not contribute to the prawn fishery at Mandapam, the seeds of this species are available in estuarine, coastal and backwater area of this locality in February-April and July-November periods. The seeds of *P. indicus* and *P. semisulcatus* for stocking were collected from coastal waters of Palk Bay at Thonithurai, about 5 km south-east of Mandapam Camp by using a nylon mosquito net of 2 m × 1m size. The collected seeds were transported in plastic containers of 47 litres capacity to the aquarium at the Regional Centre of CMFRI and acclimatised in plastic pools with running water facilities. They were kept for one week in this manner and transported to the farm site which is about 1 km from the Regional Centre.

EXPERIMENTS

Three experiments were conducted during 1978-79, one in 1978 and two in 1979.

Experiment I: This experiment dealt with the culture of *P. indicus* with food, minced clam meat and trash fishes in the pond of 450 sq.m. Before stocking the pond, netting operations revealed that it was devoid of any injurious organisms such as predatory fishes and crabs. *P. indicus* seeds were stocked in the pond at a rate of 5/m². The average total length of the seeds was 23 mm and the average weight, 0.11 gm (Plate I A). After stocking, the seeds were fed with clam meat and minced fresh trash fish at a rate of 10% of the body weight of the prawns and this rate was continued throughout the experiment. The salinity range of pond water was 33.08-35.19‰ and the oxygen content varied between 4.0 ml/l and 5.3 ml/l (Table 1). During first week of September, a slight discolouration of pond water was observed. A plankton sample collected during the period was analysed and the occurrence of *Trichodesmium erythraeum* and *Thallassiothrix fraunfeldii* was noticed. This discolouration disappeared within a period of about three days and no adverse effects of this was observed on the culture stock.

TABLE 1. *Average salinity (‰) and dissolved oxygen content (ml/l) for the months from April to September during the years* 1978-79

Month	I Experiment—1978		II Experiment—1979		III Experiment—1979	
	Oxygen	Salinity	Oxygen	Salinity	Oxygen	Salinity
April	4.8	33.08	5.0	32.12	4.5	32.12
May	4.8	33.45	5.4	31.83	3.9	31.00
June	4.0	33.88	4.5	34.00	4.1	33.89
July	5.3	35.19	5.0	34.42	5.1	34.21
August	4.6	34.02	5.3	33.69	5.2	33.64
September	4.5	34.84	5.1	34.98	4.9	33.93

The mean weight increments registered during the culture period of 158 days are shown in Fig. 1. During the first month the weight increment was 2.49 gm at the rate of 0.083 gm/day. In the following month, the prawn showed only 0.70 gm weight increase showing a daily weight increment of 0.002 gm. From the third month onwards till the end of experiment (95 days), the prawns gained 8.20 gm in weight, at a rate of 0.086 gm/day. After 158 days of culture the prawns were harvested (Plate I B). The average total length of prawns was 121 mm and the average weight, 11.5 gm (plate I C), thus showing 98 mm growth in total length and 11.39 gm in weight in the course of the culture period. The overall rate of growth in total length and by weight per day were 0.620 mm and 0.072 gm respectively. The survival rate of prawns in the experiment was 44.05% (Table 2). Totally 10.42 kg of *P. indicus* was harvested indicating a production of 231.53 kg/ha/5 months at a stocking rate of 50,000 prawn seeds/ha.

Experiment II: This experiment was also on *P. indicus* but without giving any supplementary food, but with application of inorganic fertilisers to the pond water. The pond used for culture of *P. indicus* in 1978 was utilised for the experiment. The water was completely pumped out and predatory and competitive fishes such as catfishes, *Therapon* spp and *Tilapia* which entered the pond due to breaches of bunds in cyclone, were removed by operating nets and by handpicking. Due to continuous seepage of water into the pond from sea, it was not possible to dry the pond completely even for a short duration. Agriculture lime was applied at the rate of 400 kg/ha to absorb excess carbon dioxide and supply the calcium required by the prawns during their moulting periods. After fifteen days the inorganic fertilisers, urea and superphosphate in the ratio of 4 : 1 were added to the water at the rate of 100 kg/ha. Sea water was pumped into the culture pond and the water level was maintained at 30 cm for two days and 50 cm for next three days. A good amount of phytoplankton growth was noticed. The following planktons were present in the water : *Rhizosolenia* sp, *Pleurosigma aestuarii, Thallassiosira subtilis, Navicula* sp. and a few filaments of blue green algae. There was no oxygen depletion below 2.78 ml/1 due to more production of phytoplankton and when more water was pumped in, the oxygen value raised to 6.7 ml/1 and the average pH value was 8.4. On the fifth day, the plankton produced settled at the bottom of the pond. After seven days since the application of fertilisers, on 7-4-1979, *P. indicus* seeds with an average total length of 27.5 mm weighing 0.15 gm were stocked at the rate of 5/m². Inorganic fertilisers were added once in fifteen days and the water level in the culture pond was maintained at 0.75 m. The prawns were not provided with any supplementary food. During the culture period, the average monthly salinity range was 33.08‰ to 35.19‰ and monthly average oxygen content varied between 4.5 ml/1 and 5.4 ml/1 (Table 1).

During the first 78 days the prawns gained only 2.77 gms in weight thus showing only 0.036 gm increase per day. In the following 56 days, until the 134th day, the prawns showed an average weight decrease of 0.74 gm at the rate of 0.013 gm/day (Fig. 1). During this period most of the prawns were observed to be rather lethargic with a soft body without the usual hardness of the exoskeleton. The cephalothorax appeared to be much larger for the abdomen and showed distinct disproportion when compared with

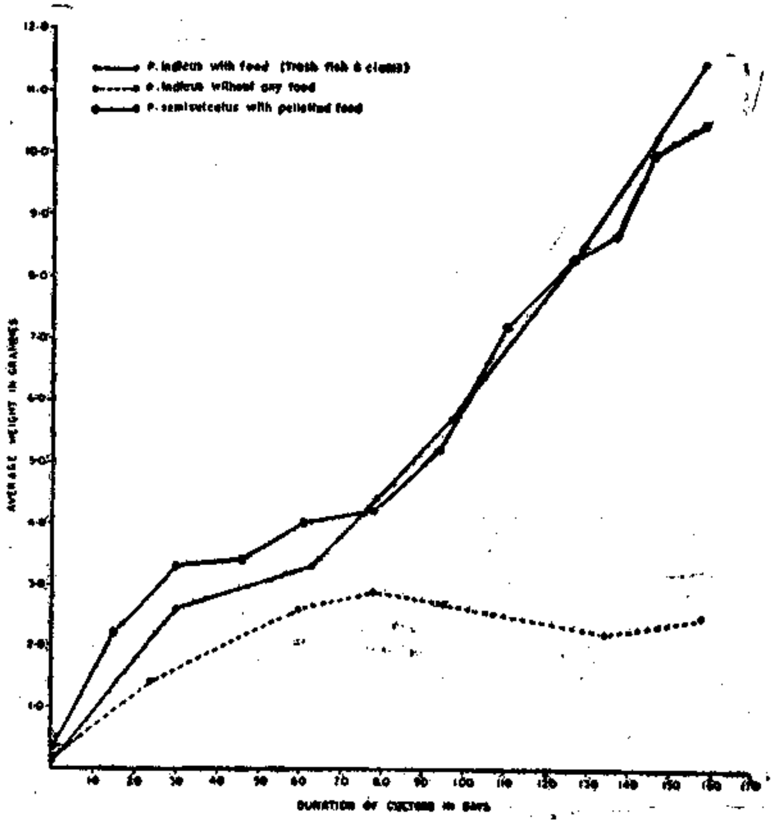

Fig. 1. Increase in average weight of prawns cultured in coastal ponds at Mandapam Camp.

TABLE 2. *Details of growth, survival and production of prawns cultured in coastal ponds at Mandapam camp during* 1978-79

Number of experiment	Species involved, food provided and duration of experiment	Stocking density per sq.m.	Initial length (mm) at the commencement of rearing	Initial weight (gm) at the commencement of rearing	At the end of 78 days: Average length (mm)	At the end of 78 days: Average increment in length (mm)	At the end of 78 days: Growth rate per day (mm)	At the end of 78 days: Average weight (gm)	At the end of 78 days: Average increment by weight (gm)	At the end of 78 days: Rate of growth by weight per day (gm)	At the end of following 80 days: Average length (mm)	At the end of following 80 days: Average increment in length (mm)	At the end of following 80 days: Growth rate per day (mm)	At the end of following 80 days: Average weight (gm)	At the end of following 80 days: Average increment by weight (gm)	At the end of following 80 days: Rate of growth by weight per day (gm)	At the end of experiment: Average increment in length (mm)	At the end of experiment: Growth rate per day (mm)	At the end of experiment: Average increment by weight (gm)	At the end of experiment: Rate of growth by weight per day (gm)	Percentage of survival at the end of experiment	Production rate (kg)/hectare/5 months
I.	*P. indicus* Food : clam meat and trash fish. Pond No. VII. Period : April-September, 1978.	5	23.01	0.11	84.2	61.2	0.776	4.40	4.29	0.054	121.0	36.0	0.450	11.50	7.10	0.089	98.0	0.620	11.39	0.072	44.05	231.53
II.	*P. indicus*. Without supplementary food. Pond No. VII. Period: April-September, 1979.	5	27.51	0.15	77.3	49.7	0.640	2.92	2.77	0.036	75.1	—2.1	—0.026	—2.52	—0.40	—0.005	47.6	0.301	2.37	0.015	37.24	47.78
III.	*P. semisulcatus*. Food : Pelletted artificial food. Pond No. VI. Period : April-September, 1979.	3	32.81	0.34	80.5	48·7	0.620	4.24	3.9	0.050	108.0	27.5	0.343	10.50	6.26	0.078	76.2	0.482	10.16	0.064	41.48	135.47

normal specimens of the same size. In the last 24 days, the prawns showed an upward trend in weight increase gaining 0.30 gm in average weight indicating 0.011 gm weight increment per day. On the 158th day the prawns were harvested. The average length and weight of prawns were 75.1 mm and 2.52 gm respectively. The average growth increment per day was 0.301 mm in total length with a daily weight increase of 0.015 gm during culture period (Table 2). The survival rate of prawns was 37.24% and the production rate was 47.78 kg/ha/5 months.

Experiment III: The third experiment was aimed at assessing survival and growth of *P. semisulcatus* in coastal ponds by providing with artificial pelletised food. After removal of unwanted fishes, agriculture lime and fertilisers were applied as done in the second experiment. In the first week of April, 1979 juveniles of *P. semisulcatus* with an average length of 32 mm and weighing 0.34 gm (Plate I, D) were stocked in the pond No. VI at a rate of 3 seeds/m^2. The prawns were fed on artificial pelletised feed compounded with fish meal (42%), tapioca powder (33%), rice bran (10%), black gram husk powder (9%), starmin powder (5%) and powdered yeast and vitamins (1%). Tapioca powder was boiled with water and other ingredients were mixed with the paste to make a dough. The pelletising was done by squeezing the dough through an ordinary hand squeezer and the product was sun-dried for three days. The analytical results of the feed were: (1) moisture 5.04%, (2) total ash 23.24%, (3) acid insoluble ash 5.77%, (4) protein 24.50%, (5) carbohydrate 22.50% and (6) fat 2.95%. The pellets retained their shape for about 45 minutes in the water. The monthly salinity range and oxygen content of the pond water during the experiment were 31.00‰ to 33.93‰ and 3.9 ml/l to 5.2 ml/l respectively (Table 1). Feeding was carried out at dusk and the prawns were observed to approach the periphery of the pond to pick the pellets immediately after the supply. The prawns were fed with the pelleted food at a rate of 20-25% of body weight of prawns.

After 15 days, the prawns gained 1.824 gm by weight at a rate of 0.120 gm increment per day. During the second fortnight the weight gain was 1.12 gm showing 0.075 gm weight gain per day. In the following 48 days, the rate of weight increment came down to 0.020 gm per day and the average weight gain was only 0.96 gm on 78th day. From then onwards, the prawns showed 0.078 gm weight increment per day and gained 6.25 gm each within eighty days (Fig. 1). The experiment was carried out for 158 days and the prawns were harvested during the third week of September (Plate I E). The average total length of prawn was 108 mm and the average weight was 10.5 gm (Plate I F), thus showing an overall growth increment of 76.2 mm in total length and weight gain of 10.16 gms. The average growth rate per day was 0.482 mm and the average weight increase was 0.064 gm per day. The survival rate was 41.48% (Table 2). The harvested prawns weighed 5.25 kg which indicated a production of 135.47 kg/ha/5 months at the stocking rate of 30,000 seeds per hectare.

Harvesting

Drag net measuring 15 m in length and 2 m in height with a mesh size of 25 mm and weights added at regular intervals of 24 cm at the foot rope, was operated to harvest *P. indicus*. Only 50% of the prawns were caught by this method while the rest were found to bury themselves at the bottom. Hence the entire pond water was pumped out and the remaining prawns were hand-picked and gathered. However when the same net was operated to harvest *P. semisulcatus* 99% of the prawns were obtained, as they were found to cling to the meshes of the net during operation of the net. The entire water from the pond was pumped out to collect the remaining cultured stock of *P. semisulcatus*.

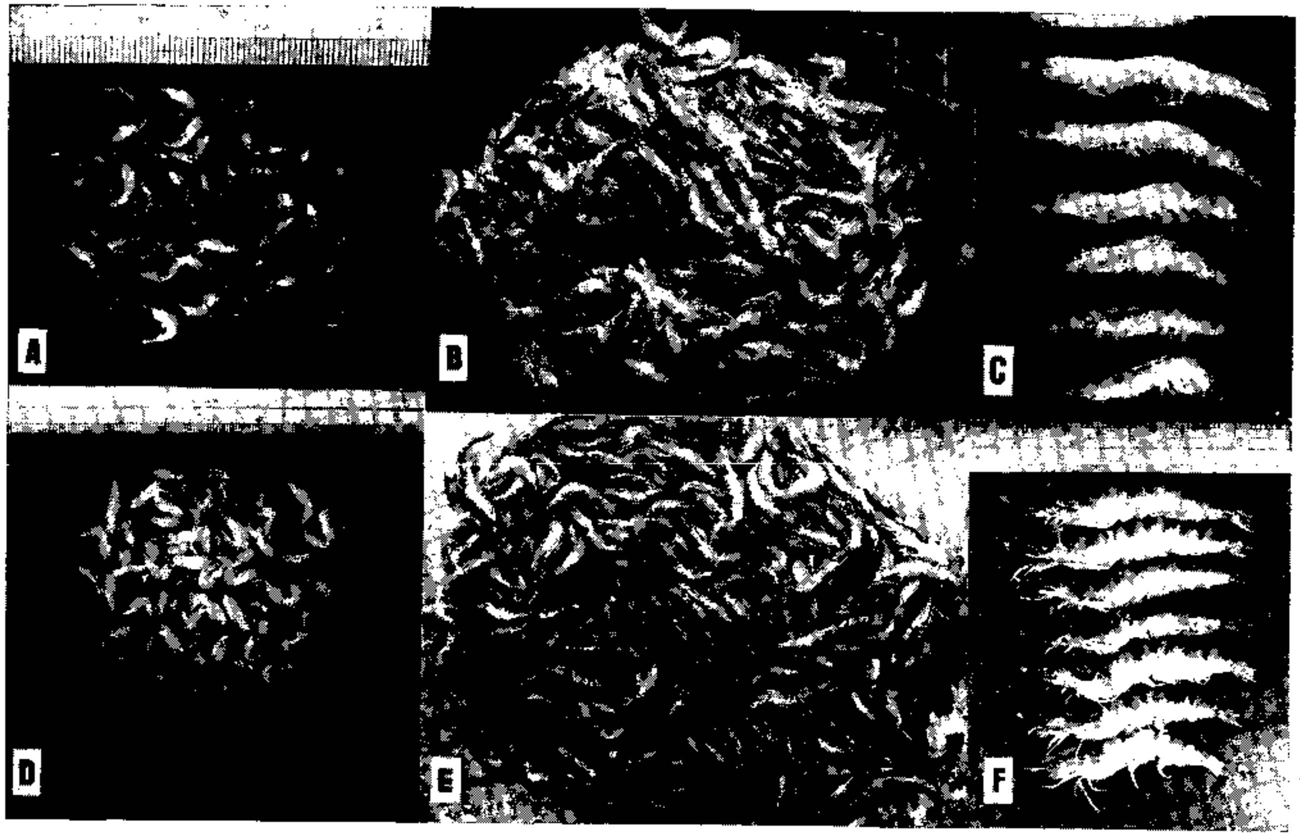

PLATE I. Stocked seeds and harvested prawns in the culture experiments at Mandapam Camp during 1978-79. A. A sample of seeds of *P. indicus* stocked in April, 1978 ; B. A sample of *P. indicus* harvested in September, 1978 ; C. Showing size range of *P. indicus* harvested ; D. A sample of the seeds of *P. semisulcatus* stocked in April, 1979 ; E. A sample of *P. semisulcatus* harvested in September, 1979 ; and F. Showing size range of *P. semisulcatus* harvested.

Competitors and Predators

Tilapia is now regarded as one of the pests in culture ponds since it is a prolific breeder and compete for space and food (Pillai, 1973). Eventhough *Tilapia* and other fishes were completely removed from the pond before commencing stocking operations, young ones of *Tilapia* in hundreds were noticed within a fortnight in the culture ponds. Males of *Tilapia* care their young ones in their mouth. While catching the adults, they immediately release them from their mouth. Attempts were made to eradicate this fish by operating gill nets and drag nets but without success. *Tilapia* posed a great problem as they were found to feed on the pelleted food provided for *P. semisulcatus* and on the plankton which developed as a result of fertilisation of the pond water in the second experiment. Although *Tilapia* was observed to consume crustaceans under crowded condition in the absence of vegetable food (Rabanal and Hasillos, 1957), when the gut contents of *Tilapia* of different sizes caught in the culture ponds on different days were analysed, they were not found to feed on prawns. Gobiid fishes of size range 10-25 mm were present in large numbers in the ponds and were observed to feed on plankton, thus competing for food with prawns. On some occasions, eagles, crows and gulls were found to pick up the prawns when they come near the edges of the ponds during morning and evening hours. Efforts were made to ward them off.

Discussion

The growth rate of 0.620 mm per day in the first experiment for 158 days and 0.640 mm in the second experiment for the first 78 days for *P. indicus* indicates a faster rate of growth than those observations made by Hall (1962), Subramanyam (1968), George (1975) in the same species and compares well with the growth rate of *P. monodon* in prawn culture ponds at Phillipines (Delmendo and Rabanal, 1956) and of *P. indicus* observed in cage culture (Rajendran and Sampath, 1975) and in Narakkal demonstration fields (CMFRI, 1978b). Sampath and Menon (1975) observed a growth rate of 0.99 mm/day in *P. indicus* during 95 days of cage culture with artificial feed. George (1961) recorded a faster daily growth rate of 1.39 mm in the brown shrimp *P. azetecus* from the estuarine environment of Louisiana (U.S.A.).

P. semisulcatus fed with pelleted feed showed 0.482 mm growth rate per day which compares favourably with those recorded by Hall (1962), Subramanyam (1968) and George (1975) for *P. indicus* and with the growth rate of *P. monodon* cultured in salt pan reservoirs at Kakinada. The rate of growth in total length and by weight of *P. semisulcatus* in this experiment are less than those of *P. indicus* cultured in the first experiment (Table 2).

The amount and quality of food required at various developmental stages are stated to have a direct relationship with growth of prawns (Kunju, 1978). The decrease in total length and weight after 78 days in *P. indicus* cultured in the second experiment without supplementary food may probably due to this factor, as environmental parameters such as, temperature, oxygen and salinity did not show any marked variation (Table 1 and 2). Slower growth rate due to non-availability of proper food after sixty days in *P. indicus* has been reported by Sampath and Menon (1975). The average daily growth rate of *P. indicus* cultured without feed were only 0.301 mm in total length and 0.015 gm by weight which works out to be only 48.54% of the growth rate per day and 20.83% in daily weight gain of the same species fed with trash fish and clam meat in the first experiment (Table 2). The survival rate is also higher in the first experiment than in the second experiment. These results confirm the necessity of supplementary feeding in prawn culture which has been dealt with earlier

(Zein Eldin, 1963). Rajendran and Sampath (1975) noticed better survival and growth rates and Sampath and Menon (1975) found faster growth in *P. indicus* which were given artificial feed in cage culture experiments in Kovelong backwaters. The slow rate of growth of *P. indicus* in the first experiment during the second month and of *P. semisulcatus* between 31 and 78 days of culture period may possibly due to some physiological stress caused by the development of secondary sexual characters as there was no lack of food, and the environmental factors such as temperature, salinity and dissolved oxygen showed no significant differences.

Kurata and Shigueno (1976) observed higher survival rate in *P. japonicus* if large fry of 1.10—6.08 gm weight were stocked in the culture ponds. Mohanty (1974) recorded higher rate of survival in the experiment when advanced juveniles of *P. indicus* were stocked and lower rate of survival where early juveniles were stocked in the brackish water ponds. From the above facts, it appears that the survival rate of 44.05% in the first experiment and 41.08% in the third experiment can be enhanced by stocking fry weighing above 1 gm.

The present studies made in this experimental prawn culture in coastal ponds at Mandapam Camp indicate the possibility of developing intensive culture operations for *P. indicus* and *P. semisulcatus* on a commercial basis in such localities.

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ON THE REARING OF PENAEID PRAWN LARVAE IN THE MEDIUM TREATED WITH TETRACYCLINE AND ACRIFLAVIN

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ABSTRACT

Experiments were conducted on rearing of larvae of *Penaeus indicus* and *Metapenaeus dobsoni* in the medium treated with tetracycline and acriflavin. Two sets of experiments were carried out with tetracycline. In one set, the medium was treated at concentrations varying from 1 ppm to 5 ppm, only in the first day of experiment while in the other set, the medium was treated daily. It was observed that hatching of eggs to nauplii and subsequent larval development to consequent stages, were not affected in the experiments conducted with 1-3 ppm tetracycline treatment in the first day. However, the continuous treatment of the same and treatment with acriflavin were found to reduce the survival rate of larvae. It was also observed that the growth of the phytoplankton which form the food of developing larvae, was affected in the medium treated with acriflavin whereas tetracycline treatment did not inhibit the algal growth. The significance of the results obtained is discussed.

INTRODUCTION

MORTALITY of larvae due to disease is one of the hurdles to be overcome for success in culture operations. Very little is known regarding the precautions to be taken for preventing the onset of infection in the course of culture. Infection and diseases are generally found to be associated with bacteria (Lightner and Lewis, 1975) and fungus (Ganaros, 1957; Lightner and Fontaine, 1973; Fisher *et al.*, 1975). The present study is carried out to understand the effect of the antibiotic tetracycline and the antifungal agent acriflavin, on survival and growth of penaeid prawn larvae.

MATERIALS AND METHODS

Experiments were carried out on larvae of *Penaeus indicus* and *Metapenaeus dobsoni* The concentrations of chemotherapeutic chemical tested, varied from 1 ppm to 5 ppm. Two sets of experiments were carried out to examine the potential effect of the antibiotic. In one, the medium was treated only once on the first day of the experiment while in the other set, the treatment was continued daily. Initially 500 ml of treated medium was taken in a 2-litre beaker to rear 50 numbers of experimental larvae. As a control, larvae were reared in pure sea water. Continuous aeration was provided during the experimental period and 50 ml of *Chaetoceros* sp. (26,000 cells to 56,000 cells/ml) was given as feed every day from the last nauplius stage onwards. In addition to the medium used for larval rearing, the sea water used for phytoplankton culture in open sunlight, was also similarly treated. It was taken in 2-litre beakers and kept in open sunlight for 24 hours after treating with chemotherapeutic chemical in different concentrations. No chemical treatment was given for the control beaker. The cell concentration was measured with haemocytometer. The salinity ranged from 31.4‰ to 34.6‰, while the temperature varied from minimum value of 27.2°C to maximun of 29.3°C in the course of larval rearing experiments. However, the temperature of the medium in the open-sunlight phytoplankton culture reached upto a maximum of

37.2°C. Normal Deviate Test and Analysis of Variation by one way classification were applied for statistical analyses of the obtained results.

RESULTS

Three trials were carried out in each experiment using different broods of larvae. In one set of experiments, larval rearing was carried out from egg stage to postlarval stage in the medium treated with antibiotic tetracycline only once in the beginning of the experiment even though the experimental duration varied from 12 to 14 days. In the second set of experiments, the antibiotic treatment to the rearing medium was given daily during the course of experiment.

In the experiment where tetracycline treatment to the medium was given only once, the average survival rate of *P. indicus* larvae from egg to postlarval stage was observed to be 13.0% in 1 ppm concentration while it was found to be 13.0%, 12.0%, 11.0%, 11.0% and 9.0% respectively in 2 ppm, 3 ppm, 4 ppm, 5 ppm and control medium. Statistical analyses revealed that the survival rate of larvae in the medium, treated with the first three antibiotic concentrations, was significantly higher than that in the control medium. However, the difference was insignificant when the survival rate of control larvae was statistically compared with that of the larvae reared respectively in 4 ppm and 5 ppm (Table 1). Similarly *M. dobsoni* larvae completed larval development with an average survival rate of 32.0%, 34.67%, 35.33%, 30.67% and 28.0% respectively in 1 ppm, 2 ppm, 3 ppm, 4 ppm and 5 ppm antibiotic media while 27. 33% of control larvae attained postlarval stage. Significantly more number of postlarvae were obtained when reared in 2 ppm and 3 ppm concentration than in the control medium.

The hatching rate of *P. indicus* eggs to nauplii stage when treated with 5 ppm antibiotic was significantly low. In the case of *M. dobsoni* eggs, significantly low hatching rates were observed in 4 ppm and 5 ppm (Table 1).

In the experiment in which antibiotic treatment was given daily during the course of experiment, hatching of *P. indicus* eggs to nauplii was similarly affected. Besides, the development and transformation to subsequent stages were observed to be prolonged. Only few of the surviving larvae reached upto mysis III stage when treated at the rate of 1 ppm per day, even after 16 experimental days.

When the treatment was at the rate of 2 ppm per day, negligible number of larvae attained only mysis I stage in 9-10 days but thereafter all the remaining larvae died when treatment was further continued. Similarly the larvae did not complete their development when daily treatment to the medium was given at the rate of 3 ppm, 4 ppm, and 5 ppm respectively. However, the control larvae successfully metamorphosed into postlarvae with a survival rate varying from 12% to 16% in 14-15 days. More or less the same pattern of results was obtained when the daily treatment was carried out in the medium used for rearing *M. dobsoni* larvae. Mortality of larvae of *P. indicus* and *M. dobsoni* was observed when the accumulation of the chemotherapeutic chemical in the medium reached concentration varying from 17 to 25 ppm.

Results of the treatment of the medium with antifungal agent, acriflavin, were not encouraging. Hatching to nauplii was adversely affected when acriflavin was applied and the larvae did not develop after protozoea I stage in all concentrations attempted eventhough acriflavin was applied only once in the commencement of the experiment. The larvae died generally after 4-6 days.

When the media for phytoplankton culture were treated with tetracycline the average

TABLE 1. *Statistical analysis of the results obtained when the rearing of* Penaeus indicus *and* Metapenaeus dobsoni *larvae was carried out in the media treated only once in the commencement of the experiment, with tetracycline and acriflavin by applying Normal Deviate Test*

Nature of Analyses	Treated *Vs.* control eggs subjected (No.)	Treated *Vs.* control nauplii obtained (No.)	Treated *Vs.* control postlarvae obtained (No.)	Z value		Result	
				for hatching	for survival	for hatching	for survival
EFFECT OF TETRACYCLINE :							
In *P. indicus* larvae :							
1 ppm *Vs* Control	100 *Vs* 100	91 *Vs* 93	13 *Vs* 9	1.9230	2.8986	I	S
2 ppm *Vs* Control	100 *Vs* 100	93 *Vs* 93	13 *Vs* 9	..	2.8986	..	S
3 ppm *Vs* Control	100 *Vs* 100	91 *Vs* 93	12 *Vs* 9	1.9230	2.2577	I	S
4 ppm *Vs* Control	100 *Vs* 100	91 *Vs* 93	11 *Vs* 9	1.9230	1.5748	I	I
5 ppm *Vs* Control	100 *Vs* 100	90 *Vs* 93	11 *Vs* 9	2.7279	1.5748	S	I
In *M. dobsoni* larvae :							
1 ppm *Vs* Control	150 *Vs* 150	140 *Vs* 141	48 *Vs* 41	0.9767	1.9456	I	I
2 ppm *Vs* Control	150 *Vs* 150	140 *Vs* 141	52 *Vs* 41	0.9767	2.9645	I	S
3 ppm *Vs* Control	150 *Vs* 150	141 *Vs* 141	53 *Vs* 41	..	3.2147	..	S
4 ppm *Vs* Control	150 *Vs* 150	130 *Vs* 141	46 *Vs* 41	3.4024	1.4034	S	I
5 ppm *Vs* Control	150 *Vs* 150	138 *Vs* 141	42 *Vs* 41	2.6542	0.2893	S	I
EFFECT OF ACRIFLAVIN :							
In *P. indicus* larvae :							
1 ppm *Vs* Control	150 *Vs* 150	122 *Vs* 130	..	3.4326	..	S	..
2 ppm *Vs* Control	150 *Vs* 150	115 *Vs* 130	..	5.7803	..	S	..
3 ppm *Vs* Control	150 *Vs* 150	123 *Vs* 130	..	3.0523	..	S	..
4 ppm *Vs* Control	150 *Vs* 150	105 *Vs* 130	..	8.4848	..	S	..
5 ppm *Vs* Control	150 *Vs* 150	121 *Vs* 130	..	3.7939	..	S	..
In *M. dobsoni* larvae :							
1 ppm *Vs* Control	150 *Vs* 150	124 *Vs* 140	..	8.7234	..	S	..
2 ppm *Vs* Control	150 *Vs* 150	130 *Vs* 140	..	6.3931	..	S	..
3 ppm *Vs* Control	150 *Vs* 150	119 *Vs* 140	..	10.2489	..	S	..
4 ppm *Vs* Control	150 *Vs* 150	118 *Vs* 140	..	10.5165	..	S	..
5 ppm *Vs* Control	150 *Vs* 150	124 *Vs* 140	..	8.7234	..	S	..

'S' *denotes* significant difference.

'I' *denotes* insignificant difference.

growth of *Chaetoceros* sp. for 24 hours was found to be 39.33 x 10^4, 40.4 x 10^4, 38.93 x 10^4, 40.4 x 10^4 and 35.6 x 10^4 cells/ml respectively in 1 ppm, 2 ppm., 3 ppm., 4 ppm. and 5 ppm. while in the control, it was found to be 38.0 x 10^4 cells/ml which differs insignificantly from that of treated ones when analysed statistically. In the medium treated with acriflavin, growth of *Chaetoceros* sp. was observed to be retarded and if at all growth was present, it was found to be negligible while average growth was 78.87 x 10^4 cells/ml in 24 hours in the control.

Discussion

It is interesting to note that significant number of *P. indicus* and *M. dobsoni* larvae attained postlarval stage in the media, treated only once in the commencement of the experiment with the antibiotic tetracycline upto 3 ppm while continuous treatment resulted in adverse effect on development.

In the case of *P. indicus* larvae, the treatment given only once in the beginning of the experiment, gives better survival rate when the dosage ranges from 1 ppm to 3 ppm. However, a dosage of 1 ppm does not significantly enhance the survival rate in *M. dobsoni* larvae but the treatment with 2 ppm and 3 ppm produces better survival rate. Hence, it may be inferred that the larvae of *P. indicus* may be more susceptible to diseases when compared to that of *M. dobsoni* as a result of which 1 ppm treatment gives significant survival in larval rearing of *P. indicus*, but not of *M. dobsoni*.

In both species, survival was poor in 4 ppm and 5 ppm which suggests that the higher concentrations are not suitable. When acriflavin was applied for fungal treatment, the larval development did not proceed beyond protozoea I stage in both *P. indicus* and *M. dobsoni*. Further, treatment with acriflavin and 5 ppm tetracycline resulted in poor hatching of *P. indicus* and *M. dobsoni* eggs thereby giving a clue that toxicity of chemotherapeutic chemical may be a factor resulting in inhibition of development.

In this context, it is of interest to note the observation of Marshall and Orr (1958) who found a corresponding decrease in feeding of copepod *Calanus finmarchicus* with increasing strength of antibiotic chloromycetin when treatment was given at the rate of 10 mg and 25 mg to 50 mg/litre. The feeding of penaeid prawn larvae depends upon the concentration of phytoplankton in the rearing medium. Hence the information regarding the effect of chemotherapeutic chemical on phytofeed of prawn larvae may help in understanding the mechanisms by which toxicity results in inhibition of growth and low survival. In the present study, the growth of *Chaetoceros* sp. has been observed to be retarded when the medium for phytoplankton culture was treated with acriflavin. Hence, it may be safely concluded that toxicity of acriflavin on hatching and on larval phytofood organisms, may result in the observed larval mortality at protozoea I stage itself, which proves the unsuitability of acriflavin in penaeid prawn larval rearing eventhough acriflavin was found to be a suitable fungicide, to be used in the culture of juvenile lobster *Homarus gammarus* (Abrahams and Brown, 1977).

In contrast to acriflavin, the antibiotic tetracycline did not affect the phytoplankton growth in all concentrations applied. From the present study it could be concluded that treating *P. indicus* and *M. dobsoni* larvae with a single treatment of tetracycline at a concentration of 1 to 3 ppm and 2 to 3 ppm respectively would not affect their survival rate.

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OXYGEN CONSUMPTION, AMMONIA EXCRETION AND RANDOM ACTIVITY IN *PENAEUS SEMISULCATUS, MACROBRACHIUM MALCOLMSONII* AND *PARATELPHUSA HYDRODROMUS* WITH REFERENCE TO AMBIENT OXYGEN

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ABSTRACT

Oxygen consumption, ammonia excretion and random activity in relation to ambient oxygen have been investigated in a marine prawn, *Penaeus semisulcatus*, a freshwater prawn, *Macrobrachium malcolmsonii* and a freshwater crab, *Paratelphusa hydrodromus*. At normoxia, *P. semisulcatus* maintained an ammonia quotient (A.Q.= volume or mole ; mole relation of ammonia excreted to oxygen consumed) of about 0.06, *M. malcolmsonii* maintained an A.Q. of about 0.08 and *P. hydrodromus* an A.Q. of about 0.25. Under hypoxic conditions all these three crustaceans showed high ammonia quotients. The 2 to 5 fold increase in A.Q. values in hypoxic conditions indicates increased protein degradation and may be of value in combating acid base balance as in the case of fishes. The random activity increased in hypoxic conditions in the case of *P. semisulcatus* and *M. molcolmsonii* whereas in the case of *P. hydrodromus* the activity decreased in hypoxic conditions indicating a dichotomy in behaviour which appears to have ecological significance. The metabolic rate decreased in hypoxic conditions in all the three species.

INTRODUCTION

INFLUENCE of environment on the energy metabolism of poikilotherms has been reviewed by Fry (1971), Wolvekamp and Waterman (1960), Kinne (1970-72) and Vernberg and Vernberg (1972). Oxygen consumption of crustaceans has been studied by several workers (Lofts, 1956 ; Subrahmanyam, 1957, 1962 ; Rao, 1958 ; Rajabai, 1961, 1963 ; King, 1965 ; Kutty 1969 ; Kutty *et al.*, 1971 ; Reeve 1969 ; Ramamurthi and Sainath Janak, 1973), but there are fewer studies combining oxygen consumption and nitrogen excretion (Reeve, 1969). In most of these cases spontaneous random activity as a factor has not been investigated. Comparison of routine metabolism can be valid only when a measure of activity is available as otherwise energy requirements can be widely different even in the resting animals at different levels of random activity (Spoor, 1946 ; Fry, 1947 ; Beamish and Mookerji, 1964 ; Kutty, 1968).

In the present study simultaneous measurements of oxygen consumption, ammonia excretion and random activity of a marine prawn, *Penaeus semisulcatus*, a freshwater prawn, *Macrobrachium malcolmsonii* and a fresh water crab, *Paratelphusa hydrodromus* exposed to various concentrations of ambient oxygen below air saturation have been investigated. Besides providing basic information on the influence of ambient oxygen on metabolism and activity of crustaceans this study gives supplementary information of value in the aquaculture of the two commercially important prawns.

MATERIALS AND METHODS

P. semisulcatus were collected from Palk Bay off Mandapam. They were kept in full sea water (salinity 33‰) in a rectangular tank

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fitted with a biological filter through which water was recirculated. *M. malcolmsonii* were collected from the river Cauvery off Tiruchirapally. They were also kept in fresh water in a rectangular tank fitted with a biological ammonia filter. Oxygen concentration of the water present in these tanks was always kept near air-saturation. The water in these tanks was partially changed once in a week. The prawns were fed *ad lib* with earthworms. The uneaten food and faeces were removed everyday by siphoning.

Field crabs *P. hydrodromus* were collected from paddy fields around Madurai and were maintained in freshwater. They were also fed *ad lib* with earthworms.

P. semisulcatus used for the experiments were of 13.9 ± 2.07 g. in weight (n = 3) and 128 ± 4.62 mm in total length. *M. malcolmsonii* used for the study were of 31.94 ± 0.48 g. in weight (n=5) and 194.4 ± 0.18 mm in total length. *P. hydrodromus* used for experiment were of 36.6 ± 0.18 g. in weight (n=3) and 50.00 ± 0.58 mm in carapace width. The water temperature in the acclimation tanks was 29 ± 1°C and the animals were tested in the same temperature. All the three crustaceans were acclimated at least for two weeks before experiment and tested under acclimation conditions. The animals were starved for 24 hours (Fromm, 1963; Beamish, 1964) before experiment.

Apparatus

The apparatus used for the present study has been described by Kutty *et al.* (1971). Mainly it consisted of two units, an electronic counter and a transparent plastic perspex respirometer.

Experimental procedure

These experiments were done using modified Fry's respirometer. The duration of an experiment lasted for 60 minutes except the last one in which the ambient oxygen was allowed to reduce until the animal was aspyxiated (loss of equilibrium).

The focus lights beamed at the photocells were switched on at least 30 minutes before starting a day's experiment. At the start of the experiment, initial samples were collected and the circulation of water through the respirometer was cut off. After an interval of 60 minutes, final samples were collected. In each sampling time (initial and final of each run), two separate water samples were collected for analysis of dissolved oxygen and ammonia. The size of each sample was 30 ml for oxygen and 15 ml for ammonia (25 ml collected first for rinsing was discarded). Care was taken during sampling to compensate the sampling water by allowing water to flow into the respirometer. The figure in the activity counter was recorded immediately after sampling (initial and final sampling of all the runs).

After sampling the final samples of Run I, the respirometer was not opened to the circulating water but approximately 70 ml of the crustacean medium was circulated once or twice through the respirometer for mixing it with the 'respired' water remaining unflushed in the respirometer. Then the initial samples of next run (as described above) were collected. The overall time for sampling and adding water was about 2 minutes. To avoid using the correction factor for the initial oxygen concentration of second and the successive runs, the above mentioned procedure was followed by taking initial samples. During the last run, the final samples were collected only after the animal reached the asphyxial oxygen level, as indicated by the beginning of the equilibrium loss of the animal. Then the respirometer was flushed with the air-saturated water to revive the animal. The concentrations of oxygen and ammonia were determined in the samples acquired at the beginning and at the end of each closure period. The activity was counted by the difference between the initial and final figure of the activity counter, which was noted immediately after each sampling.

Methods of Water Analysis :

(i) *Dissolved oxygen*: The unmodified Winkler method was followed (American Public Health Association, 1965). The size of the sample used for titration was 25 ml.

(ii) *Ammonia* : Ammonia concentration in the water samples was estimated by an improved Phenol hypochlorite method (Harwood, 1970). The size of the sample used for estimation was 10 ml. and the ammonia contents in the water samples were determined colorimetrically using Spectronic 20 at a wavelength of 630 ml.

RESULTS

The results of the experiments on oxygen consumption, NH_3 excretion, A.Q. and random activity in *P. semisulcatus, M. malcolmsonii* and *P. hydrodromus* subjected to a hypoxic phase until the animals were asphyxiated in a closed respirometer are represented graphically in Fig 1. The ambient oxygen concentrations were categorised into three levels (high, medium and low) (Table 1). In high ambient oxygen concentration *P. semisulcatus* showed the highest rate of oxygen consumption followed by *M. malcolmsonii* and *P. hydrodromus*. *P. semisulcatus* showed the highest rate of ammonia excretion in high ambient oxygen concentration followed by *P. hydrodromus* and *M. malcolmsonii*. In high ambient oxygen concentration *P. hydrodromus* showed the highest random activity and *P. semisulcatus* the least.

The trends in oxygen consumption decreased with decrease in ambient oxygen in all the three species tested. The decrease in the rate of oxygen consumption was most significant in *P. semisulcatus* and less significant in *P. hydrodromus*. The rate of ammonia excretion increased with decrease in ambient oxygen in all the three species. The random activity increased in *P. semisulcatus* and *M. malcolmsonii* with decrease in ambient oxygen but in the case of *P. hydrodromus* the random activity decreased with decrease in ambient oxygen concentration.

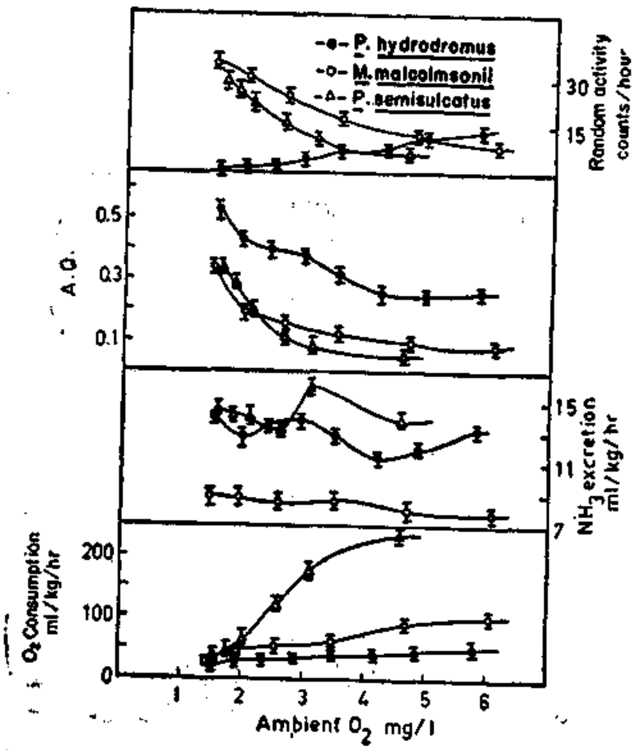

Fig. 1. Oxygen consumption, NH_3 excretion, A.Q. and random activity in relation to ambient oxygen in *P. semisulcatus, M. malcolmsonii* and *P. hydrodromus* acclimated to and tested at 29± 1°C. Each value plotted is a mean of (± S.E.) 5 determinations in the case of *M. malcolmsonii* and 3 determinations each in the case of *P. semisulcatus* and *P. hydrodromus*.

TABLE 1. *Oxygen consumption, NH_3 excretion, A. Q. and random activity in* P. semisulcatus, M. malcolmsonii *and* P. hydrodromous *at* 29± 1°C

Species	Ambient (O_2 mg/l)	Random activity (counts/hr)	Rate of O_2 consumption (ml/kg/hr.)	Rate of NH_3 excretion (ml/kg/hr.)	A.Q.	Remarks
P. semisulcatus	High (4.55—4.63) (4.60± 0.04)	5± 0.58	232.3± 1.62	13.9± 0.11	0.06± 0.0001	Acclimated to and tested in full sea-water (33‰)
	Medium (2.01—3.49) (2.7± 0.20)	16.3± 1.62	125.4± 16.13	14.5± 0.53	0.13± 0.017	,,
	Low (1.62—1.81) (1.70± 0.04)	27.3± 0.88	46.1± 1.64	14.2± 0.30	0.31± 0.100	,,
M. malcolmsonii	High (6.05—6.24) (6.10± 0.03)	8.8± 0.92	99.5± 0.42	7.8± 0.18	0.08± 0.001	Acclimated to and tested in fresh-water.
	Medium (2.53—4.79) (3.60± 0.23)	18.3± 1.50	73.1± 3.86	8.4± 0.15	0.12± 0.001	,,
	Low (1.39—1.86) (1.70± 0.06)	33.1± 0.78	36.3± 3.56	8.8± 0.15	0.27± 0.025	,,
P. hydrodromus	High (5.02—5.80) (5.60± 0.19)	13.0± 0.41	48.7± 3.44	12.3± 0.81	0.25± 0.013	Acclimated to and tested in fresh-water.
	Medium (2.78—4.30) (3.80± 0.23)	7.20± 0.80	41.3± 1.55	12.6± 0.40	0.31± 0.016	,,
	Low (1.52—2.48) (1.90± 0.12)	1.4± 0.38	30.2± 1.01	13.5± 0.35	0.46± 0.024	,,

Discussion

The present study shows that in the case of crustaceans as well, the relative ammonia excretion, as evident from the A.Q. is increasing under hypoxic conditions, in agreement with earlier observation on fishes, *Tilapia mossambica* (Kutty, 1972) *Rhinomugil corsula* (Kutty and Peer Mohamed, 1975) and in gold fish and *Barbus sarana* (Peer Mohamed, 1974). Thus it appears that under anaerobic conditions induced by hypoxia there is increase in protein degradation and N-excretion in crustaceans as was suggested earlier (Kutty, 1972). It would appear that the ammonia produced may be of value in combating acidosis caused due to hypoxia and also perhaps in Na^+ conservation. In the two prawns tested there was clear increase in random activity under hypoxia but for the crab a decrease in activity was observed. This again suggests, as observed earlier in the case of teleosts *Chanos chanos* (Ameer Hamsa and Kutty, 1972) and *T. mossambica* (Peer Mohamed, 1974) that there is a dichotomy in behavioural evolution as evident from the two distinct paths in random-activity-ambient oxygen relation. Both kinds of behaviour can expected to be of value to the species concerned for survival, for increase in activity might allow the animal to escape from a hypoxic environment and decrease in activity might help the animal in conserving the limited source of oxygen available.

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A CASE STUDY OF THE ECONOMICS OF A TRADITIONAL PRAWN CULTURE FARM IN THE NORTH KANARA DISTRICT, KARNATAKA, INDIA

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Abstract

Economics of a traditional prawn culture farm situated on the northern bank of Badagani River near Haldipur in the North Kanara District, Karnataka, India is studied. The farm extends over 0.78 hectare and has a single wooden sluice gate. Culture of *Penaeus indicus, P. monodon, Metapenaeus monoceros* and *M. dobsoni* was initiated in January and continued up to May 1979. The traditional practice of trapping and holding was followed in stocking the farm. In all, 375 kg of prawns valued at Rs. 10,470.00 were harvested of which 52% comprised *P. indicus* and *P. monodon*. A profit of Rs. 7,770.00 was earned by the entrepreneur after meeting expenditure on the farm. An overall review of the economics of prawn culture in the area is given.

Introduction

The role of coastal aquaculture in integrated rural development has been recognised and development of rural communities dependant on aquaculture as main economic activity has received active consideration in the recent past.

The present study is a beginning in the direction of meeting the long-felt need of fish farmers of the area to have vital information on the economics of traditional culture practices. Though the study is confined to a small farm and limited to the first half of 1979, all the same, the information presented on vital statistics of inputs and returns if supplemented by additional data from other farms of the area will be of prime importance in planning development schemes on the aquaculture front in future.

Location

The farm (Lat. 14°22'N ; Long. 74°25'E) is situated near Haldipur adjoining the National Highway No. 17 on the northern bank of Badagani River (Fig. 1). The Badagani River is a tributary of Sharavati River. It originates at Chandaver, skirts Haldipur and meets Sharavati at Honaver near its confluence with the Arabian Sea. The Badagani River is the source of brackish water for the culture farm.

Description

The farm of area 0.78 hectare has clay bunds of 3 m height and 2.5 m width. The bottom of the farm is an admixture of clay and sand, the former predominating. In December 1978, the farm was laid and kept ready by the entrepreneur for traditional prawn culture, i.e., trapping-cum-holding. Fertilization of the pond was not done. The water level in the pond was maintained at 0.6-0.9 m throughout the period of culture.

The water supply to the farm from the Badagani River was maintained through a diversion—the feeder channel. The intake of brackish water was controlled through a sluice fixed on the western side of the farm. The rectangular wooden sluice box of size 1.2 × 1.0 m had sliding shutters placed in grooves for regulating the intake and outflow of water. The sluice box was removed from the farm after the harvest in May.

Stocking and Harvesting

Stocking

In January 1979, brackish water (with prawn seed) was let in the farm for 14 days, particularly 3 days before and 3 days after full and new moon. A petromax lamp was kept near the sluice gate to attract more prawn seed into the farm. The stocking was thus done by trapping the juvenile prawns which were allowed to enter the farm at high tide. In addition to the shutters, a nylon screen was fixed at the sluice gate to prevent the escape of juvenile prawns and seed from the farm at neap tides. The seed were allowed to grow in the farm for over a month. Artificial feeding was not resorted to.

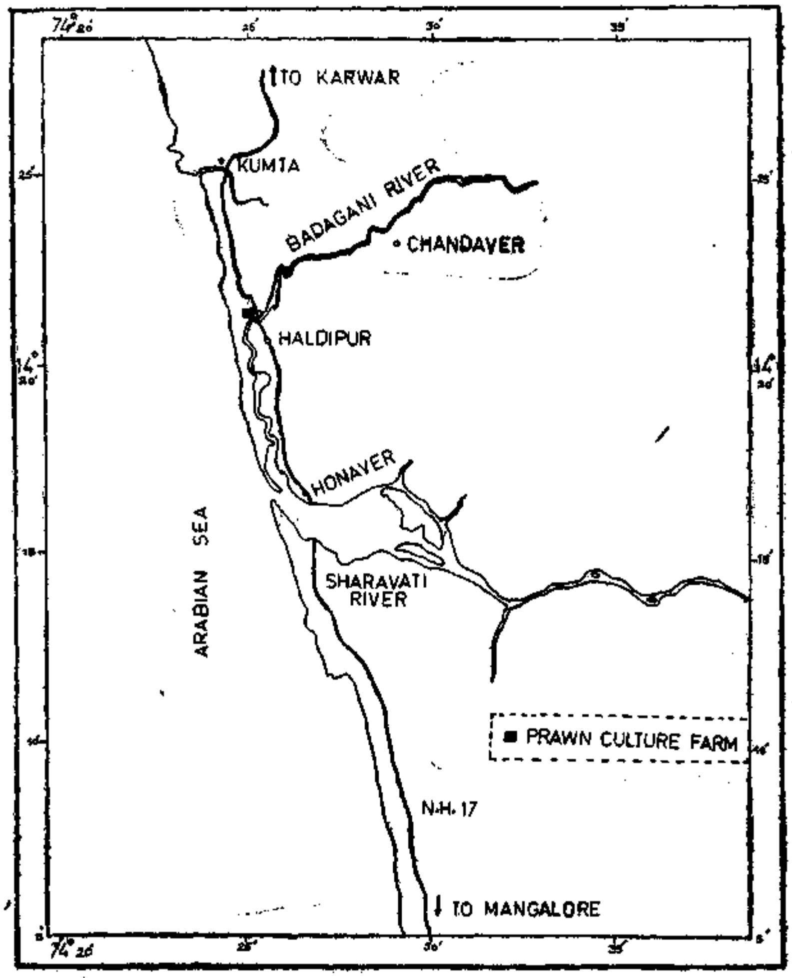

Fig. 1. Location of prawn culture farm

A collection of seed made in January from the feeding channel comprised *Penaeus indicus* of size 7-26 mm, *P. monodon* of size 10-30 mm. *Metapenaeus monoceros* of size 12-30 mm, and *M. dobsoni* of size 12-27 mm.

Harvesting

The harvesting operations were started from 23rd February. Like stocking, harvesting was also done for 7 days every fortnight.

Gear and mode of operation

A conical bag net of length 10 m and diameter 2 m at the mouth, and fabricated from nylon monofilament was used for harvesting. The mesh varied from 0.8 cm at the cod end to 2.5 cm at the mouth of the net.

As soon as the tide starts ebbing, the mouth of the bag net is fixed to the sluice gate, and the nylon screen and shutters are removed. The water gushes out from the farm through the sluice and thus gets filtered. Prawns escaping through the sluice gate get caught in the cod end of the net. The operation is continued for about 3 hours at a stretch and the catch accumulating in the cod end is taken out. Harvesting is generally done during night. As in stocking operations, in harvesting too, petromax lamps are used to attract prawns towards the sluice.

Hand picking

This practice is followed to collect prawns from the farm bed when the entire farm is almost completely drained at the end of the season.

Catch

The particulars of prawns harvested during the first half of 1979 are given in Table 1. As seen from the table, of the total yield of 375 kg of prawns harvested during the entire period, *P. indicus* aggregated as much as 150 kg. This was followed by *M. monoceros* (120 kg), *M. dobsoni* (60 kg) and *P. monodon* (45 kg). Quality prawns, viz., *P. indicus* and *P. monodon* together constituted 52% of the total catch. The catches of *P. indicus* were better in April and May (55 kg and 45 kg respectively); the yield of *P. monodon* showed only marginal variations between months. The catches of *M. monoceros* were better in February and April (35 kg and 33 kg respectively). The yield of *M. dobsoni* was maximum in May (20 kg).

TABLE 1. *Prawn harvest from the culture farm situated near Haldipur from February to May* 1979

	Prawns (kg)				
	P. indicus	*P. monodon*	*M. monoceros*	*M. dobsoni*	Total
February	15	—	35	15	65
March	35	15	26	15	91
April	55	16	33	10	114
May	45	14	26	20	105
Total	150	45	120	60	375

As is only to be expected because of the growth factor involved, the catches were on the increase with the advancement of the period of culture. The highest yield aggregating 114 kg was registered in April.

The range in size of different species of prawns harvested during the culture period were 75-145 mm for *P. indicus*, 70-135 mm for *P. monodon*, 57-70 mm for *M. monoceros* and 39-49 mm for *M. dobsoni*.

ECONOMICS OF PRAWN CULTURE

The economics of prawn culture can be studied from four angles, namely, capital investment; recurring expenditure; sale proceeds from harvest; and profit/loss.

The economics of prawn culture is presented in Table 2. Capital investment on the farm involving construction of bunds and levelling, and fabrication of sluice gate, bag net and nylon screen was of the order of Rs. 2,700. Of this, a major part aggregating Rs. 2,000 was spent on construction of bunds and levelling the farm. The recurring expenditure towards strengthening of bunds, depreciation on sluice gate, bag net and nylon screen, labour charges for harvesting the crop and watch and ward, and miscellaneous contingencies amounted to Rs. 2,700. The prevailing market rates for different species of medium-sized prawns were Rs. 60/kg for *P. monodon*, Rs. 45/kg for *P. indicus*, Rs. 6/kg for *M. monoceros* and Rs. 5/kg for *M. dobsoni*. The sale proceeds of 375 kg of prawns aggregated Rs. 10,470. If recurring expenditure on the farm is deducted from the sale proceeds, a gross profit of Rs. 7,770 was earned by the entrepreneur.

TABLE 2. *Economics of prawn culture*

	Rs.
A. *Capital Investment*	
1. Construction of bunds and levelling	2,000.00
2. Construction of sluice gate	400.00
3. Fabrication of bag net and nylon screen	300.00
Total	2,700.00
B. *Recurring Expenditure*	
1. Strengthening of bunds	1,200.00
2. Depreciation on sluice gate	100.00
3. Depreciation on bag net and nylon screen	50.00
4. Labour charges for harvesting the crop and watch and ward	1,050.00
5. Miscellaneous contingencies, viz., ice, marketing, etc.	300.00
Total	2,700.00
C. *Financial Returns*	
Sale proceeds of 375 kg of prawns	10,470.00
Less recurring expenditure	2,700.00
Profit[1]	7,770.00

[1] Exclusive of rental of farm area and interest on capital investment and recurring expenditure.

The present study, covering as it does, the economics of prawn culture in a small area with proprietory rights gives a somewhat enhanced picture of the profitability of a culture scheme. The profit would have been much less, had the land been taken on rental and institutional finance raised by the culturist. If the rental of the farm and interest at 15% on the capital investment and recurring expenditure are run down on the gross profit, a profit of Rs. 4,960 would reach the hands of the entrepreneur. After further allowing recoupment of capital investment, the net profit on the operations would be Rs. 2,260 which is a return of 80% on the capital and is quite attractive. The particulars of location, financial returns, etc., of two prawn culture farms of North Kanara District are given in Table 3.

TABLE 3. *Particulars of location, season, area, returns and profit/ha of two prawn culture farms in the North Kanara District*

Location	Season (October-May)	Area (ha)	Returns (Rs.)	Profit (Rs.)	Profit (Rs./ha)
Keppekurve (Kumta)	1965-66		76,130	73,230	6,032
	1966-67	12.14	24,498	21,297	1,734
	1967-68		72,406	69,006	5,684
Asnoti (Karwar)	1976-77		539,500	346,650	6,660
	1977-78	81.00	374,250	230,975	2,852
	1978-79		372,750	229,925	2,839

In the present study, prawn production per hectare worked out to 480 kg. A comparison of yield of prawns from such operations from other parts of the country reveals that better results have been obtained elsewhere. The yield of prawns from the low-lying, 'bheries' of West Bengal ranged between 158 kg/ha and 672 kg/ha (Verghese, 1980). Menon (1954) has arrived at an average annual yield of 1079 kg/ha and George *et al.* (1968) have given a return of 514 kg/ha in Kerala. A traditionally operated field at Vypeen Island in Kerala yielded 637 kg/ha (Gopalan *et al.*, 1980). In general, production from traditional culture farms in Kerala has shown a decreasing trend through the last few years (Gopalan *et al.*, 1980). The possibility of traditional culture practices giving small returns in future years cannot be ruled out unless modern technological innovations are incorporated into the system.

CONCLUSION

The vast 'gazani' areas of North Kanara have been under traditional prawn culture for the past few decades. In general, the traditional practice of trapping-cum-holding has the severe limitation of low production, poor quality and growth, uneconomic varieties, and above all, the menace of predators. With the support of managerial skills, institutional finance, improvements in quantum and quality of inputs, and selective stocking of fast growing species such as *P. indicus* and *P. monodon* either separately or together or in combination with compatible fishes instead of following the traditional practice in these areas, the small-scale culturist can look forward to a bright future. But saddled as he is with the limitation of small holding yielding small returns, it is imperative that large co-operatives be organised by involvement of fish farmers with rich experience of traditional farming so that better returns can be had from extensive farms. This will give a further boost to the export-oriented prawn farming industry.

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EXPERIMENTS ON MIXED PRAWN FARMING IN BRACKISHWATER POND AT KAKDWIP

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ABSTRACT

Experiments on mixed culture of postlarvae and fry of *Penaeus indicus* H. M. Edwards, *P. monodon* Fab., *Metapenaeus monoceros* Fab., *M. brevicornis* (H. M. Edwards) and *Palaemon styliferus* H. M. Edwards were conducted in a pond of 0.02 ha in the year 1978. Four short-term crops of 80 days each, without any supplementary feeding were harvested from the pond. Stocking was done @ 2 lakh/ha with varying species ratios. Pond was treated with poultry manure (1000 kg/ha/yr) and urea + superphosphate (250 kg/ha/yr each) during the course of the experiments.

While conducting the experiments, salinity of the ambient water was observed to have definite influence on growth, survival and production of prawns. Best growth of prawns, attaining the size of 97.3/7.0 and 100.0 mm/8.0 g for *P. indicus*, 172.2/50.0 and 110.0 mm/15.0 g for *P. monodon*, 100.0/7.0 and 90·0 mm/6.0 g for *M. monoceros*, 86.2/5.0 and 80.0 mm/4.0 g for *M. brevicornis* and 68.3/2.5 and 90.0 mm/3.0 g for *P. styliferus* with the survival of 57.2 and 55.0, 5.0 and 13.4, 34.2 and 17.0, 20.0 and 11.2 and, 72.5 and 33.4% for the above species respectively and the productions of 475.0 kg/ha and 310 kg/ha were obtained in first and second culture experiments respectively, covering the periods of January-March and April-June having the higher average salinity of 11.99 and 16.77 ppt. respectively. On the contrary, complete mortality of *P. indicus* and poor growth and survival for other prawns i.e. 70.0/3.8 and 13.2, 51.9/2.0 and 20.0, 53.0/2.0 and 5.0 and, 57.7 mm/2.2 g and 22.6% for *P. monodon*, *M. monoceros*, *M. brevicornis* and *P. styliferus* respectively with very low production of only 50.0 kg/ha were obtained in the third crop covering the period of July-September when the salinity abruptly went down from 16.77 ppt. to 5.08 ppt in average due to heavy rains. In the fourth experiment, although complete mortality for *P. indicus* was observed, improved growth for other prawns, attaining the size of 123.0/17.2, 85.9/5.5, 80.5/4.5 and 60.0 mm/2.5 g for *P. monodon*, *M. monoceros*, *M. brevicornis* and *P. styliferus* with the survival of 25.0, 32.6, 52.5 and 56.9% respectively and increased production of 350 kg/ha was obtained in the culture period of October-December when salinity was observed to gradually drop and ultimately stood stable at 4.08 ppt in average.

The present experiments, thus, point to the fact that sudden dropping of salinity is harmful for prawns cultured in ponds. On the contrary, constant high/low or gradually increasing/decreasing salinity may not affect much the prawns excepting *P. indicus* which definitely likes higher salinity, preferably above 10.0 ppt.

The average dissolved oxygen and temperature of the ambient water were seemingly favourable being 9.2 and 27.4, 9.8 and 33.8, 8.0 and 32.1 and 8.3 ppm and 27.9°C for first, second, third and fourth culture experiments respectively.

However, the total production of 1185.0 kg/ha from 4 crops in a year from such mixed prawn farming is considered encouraging and highest so far reported from deltaic Sunderbans region of West Bengal.

Introduction

PRAWN farming has raised much interest all over the world especially in view of demand of brackishwater prawns in international market. The culture practices in Malaysia and Singapore involve several penaeid prawns (Tham, 1955; Hall, 1962). Prawn catching from brackishwater ponds in Formosa (Kestevan and Job, 1957) and 'Sugpo' culture in Philippines (Villadolid and Villaluz, 1951; Delmendo and Rabanal, 1955; Borja and Rasalan, 1968 and Rabanal, 1977) have also been reported.

Culture of prawns in ponds in countries like Japan, Taiwan and Philippines has also attracted the attention of fishery workers. In India, Menon (1954); Evangeline (1969); and recently Ghosh, *et al.* (1972); Nair, *et al.* (1975) and Suseelan (1976) have reported about certain experiments carried out on prawn farming. However, a wide gap exists in the knowledge of culturing prawns on scientific lines in vast areas of lower Sunderbans. Recently, Das and Chakrabarti (1979) pointed out the possibility of short-term culture of prawns involving penaeids, metapenaeids and palaemonids in brackishwater ponds at Sunderbans with fairly good production.

The present experiments were taken up to further increase the production through scientific management practices of short-term mixed prawn farming involving the species—*Penaeus indicus* H. M. Edwards, *P. monodon* Fabricius, *Metapenaeus monoceros* Fabricius, *M. brevicornis* (H. M. Edwards) and *Palaemon styliferus* H. Milne Edwards, in brackishwater pond of Kakdwip Research Centre, Central Inland Fisheries Research Institute, Kakdwip.

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Materials and Methods

Mixed seed of prawn and fish were collected from the local Muriganga river of Hooghly estuary through Midnapore type of shooting net and ordinary spawn collecting drag net (mesh about 2 mm); segregated and healthy prawn seed were acclimatised to the pond condition for 1-2 hrs. and released in the prepared pond.

The technique of preparation of pond includes drying, exposing the pond bottom to sun and fertilizing the pond with urea + superphosphate, each 250 kg/ha/annum and poultry manure, 1000 kg/ha/yr in monthly instalments.

The water management technique followed was more or less in the same line described by Das and Chakrabarti (1979). In addition to these measures, marginal and submerged grasses were allowed to grow, cut leaves of date-palm, coconut etc. were spread in the culture pond. These leaves were observed to develop periphyton on them and thus serve as grazing as well as resting place for the moulting and developing prawns.

Experiments were conducted in a pond of 0.02 ha in 1978. Prawns were stocked @ 2 lakh/ha in each of the short-term croppings with varying species ratios. Growth and survival of prawns were finally recorded after complete dewatering the culture pond at the end of each experiment. Physico-chemical conditions of the pond water were recorded fortnightly.

Results and Discussions

Prawas were reared for 80 days in each culture experiment. Four crops could be harvested from the same pond in one year. The details of the experimental results are presented in Table 1.

TABLE 1. *Results of the mixed prawn culture experiments in relation to the observed physico-chemical conditions of the pond water*

Culture period (months)	Species	No. stocked	Av. size at stocking (mm/g)	Av. size at harvest (mm/g)	Survival (%)	Production crop (kg/ha)	Total production (kg/ha)	Av. water depth (cm)	Av. Temperature (°C)	Av. salinity (ppt)	Av. D.O. (ppm)	Av. pH.
	P. indicus	1000	24.0/0.250	97.3/7.0	57.2							
January	*P. monodon*	200	90.0/5.0	175.2/50.0	5.0							
to	*P. styliferus*	2000	26.0/0.250	68.3/2.5	72.5	475.0		47.0	27·4	11.99	9·2	8.4
March	*M. monoceros*	500	12.0/0.150	100.0/7.0	34.2							
	M. brevicornis	300	20.0/0.200	86.2/5.0	20.0							
	P. indicus	500	20.0/0.200	100.0/8.0	55.0							
April	*P. monodon*	500	20.0/0.200	110.0/15.0	13.4		1185.0					
to	*P. styliferus*	2000	23.0/0.200	70.0/3.0	33.4	310.0		54.0	33.8	16.27	9.8	8.9
June	*M. monoceros*	500	9.0/0.050	90.0/6.0	17.0							
	M. brevicornis	500	16.0/0.150	80.0/4.5	11.2							
	P. indicus	1000	20.0/0.200	—	—							
July	*P. monodon*	500	10.0/0.020	70.0/3.8	13.2							
to	*P. styliferus*	500	20.0/0.200	57.7/2.2	22.6	50.0		68.3	32.1	5.08	8.0	8.8
September	*M. monoceros*	1000	22.0/0.200	51.9/2.0	20.0							
	M. brevicornis	1000	16.0/0.150	53.0/2.0	5.0							
	P. indicus	500	20.0/0.200	—	—							
October	*P. monodon*	200	97.0/6.0	123.0/17.2	25.0							
to	*P. styliferus*	800	25.0/0.300	60.0/2.5	56.9	350.0		57.8	27.9	4.08	8.3	8.6
December	*M. monoceros*	500	15.0/0.150	85.9/5.5	32.6							
	M. brevicornis	2000	20.0/0.200	80.5/4.5	52.5							

During the course of the experiments, the salinity of the ambient water was observed to have definite influence on growth, survival and ultimate production of prawns. Best growth of prawns, attaining the size of 97.3/7.0 and 100.0 mm/8.0 g for *P. indicus*, 172.2/50.0 and 110.0 mm/15.0 g for *P. monodon*, 100.0/7.0 and 90.0 mm/6.0 g for *M. monoceros*, 86.2/5.0 and 80.0 mm/4.0 g for *M. brevicornis* and 68.3/2.5 and 90.0 mm/3.0 g for *P. styliferus* with the survival of 57.2 and 55.0, 5.0 and 13.4, 34.2 and 17.0, 20.0 and 11.2 and, 72.5 and 33.4% respectively and the productions of 475.0 kg/ha and 310 kg/ha were obtained in first and second culture experiments. The former experiment covered the period January-March and the latter April-June, when higher average salinity of 11.99 and 16.77 ppt. prevailed.

On the contrary, complete mortality of *P. indicus* and poor growth and survival for other prawns i.e. 70.0/3.8 and 13.2, 51.9/2.0 and 20.0, 53.0/2.0 and 5.0 and, 57.7 mm/2.2 g and 22.6% for *P. monodon, M. monoceros, M. brevicornis* and *P. styliferus* respectively with very low production of only 50.0 kg/ha were obtained in the third culture experiment during July-September when the average value of salinity went down abruptly from 16.77 to 5.08 ppt. In the fourth experiment, although complete mortality for *P. indicus* was observed, improved growth for other prawns, attaining the size of 123.0/17.2, 85.9/5.5, 80.5/4.5 and 60.0 mm/2.5 g for *P. monodon, M. monoceros, M. brevicornis* and *P. styliferus* with the survival of 25.0, 32.6, 52.5 and 56.9% respectively and increased production of 350 kg/ha was obtained in the culture period of October-December when salinity was observed to gradually drop down and ultimately stood stable at 4.08 ppt. in average.

The present experiments, thus, point to the fact that sudden drop of salinity is harmful for prawns cultured in ponds. On the contrary, constant high/low or gradually increasing/decreasing salinity may not affect much the prawns excepting *P. indicus* which definitely likes higher salinity, preferably above 10.0 ppt.

Other physico-chemical parameters like water depth, temperature, pH and dissolved oxygen as observed can be considered favourable to the culture of prawns in pond condition.

The above findings are also supported by the results obtained in earlier experiments conducted on the culture of *P. monodon*, (Varghese, *et al.*, 1975) and culture of prawns, (Das and Chakrabarti, 1979) in brackishwater ponds at Kakdwip.

The gross production of 1185.0 kg/ha/yr obtained with mixed culture of five species of brackishwater prawns may be considered as impressive compared to earlier experiments where gross productions were 360 kg/0.5 ha/annum, (Menon, 1959); 125.0 kg/0.5 ha/annum, (Evangeline, 1969); 300-800 kg/ha/yr, (Rabanal, 1977) and 666.0-850.0 kg/ha/270 days, (Das and Chakrabarti, 1979). The total production of 1185.0 kg/ha/yr as obtained in the present experiment, thus clearly indicates that by adopting short-term prawn farming technique, production of prawns can considerably be increased from unit area in a given time compared to the earlier productions of 666.0-850.0 kg/ha/270 days, (Das and Chakrabarti, 1979) from mixed prawn farming in deltaic Sunderbans of West Bengal.

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EXPERIMENTS ON SHRIMP FARMING IN KOVALAM BACKWATERS OF TAMIL NADU

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ABSTRACT

The extensive backwaters of Kovalam about 36 km south of Madras city is a potential area for intensive shrimp farming. In the absence of suitable flat clay banks in the area for farming and pending completion of traditional farm layout, shrimp culture was carried out in suspended nylon net cages as well as in pens and similar improvised facilities. Seeds of *Penaeus monodon* and *P. indicus* from nearby tidal creeks were utilised fully for rearing. The closure of the estuarine mouth by a sand bar for over five months in a year considerably altered the hydrographical conditions, yet shrimp culture was carried out successfully in the area. Emphasis was given on intensive feeding with feed balls made with the waste products of frog leg processing industry. The conversion of feed into shrimp flesh was found to be satisfactory. Periodical intensive surveys for prawn seed availability were also carried out in this area to augment juvenile supplies. The results of these observations correlated with the hydrological conditions of the backwaters for over the past four years are presented in this paper. A full account on shrimp feed formulation with the pelletiser and its beneficial effect on shrimp growth is also discussed.

The emphasis of the work had been to develop a package of practises for successful shrimp farming suitable for the private enterpreneurs under the agro-climatic conditions existing in Tamil Nadu.

INTRODUCTION

PRELIMINARY observations were made on the culture of prawn in nylon cages erected in the Kovalam backwaters near Madras (Isaac Rajendran and Sampath, 1975, Sampath and Ramachandra Menon, 1975, Siddharaju and Md. Sultan, 1980). The results of the detailed experiments on the culture of prawns in different types of enclosures under various stocking densities using different types of artificial feeds during 1975-79 are presented in this communication.

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PHYSIOGRAPHY

Kovalam backwaters situated in Chingleput District in latitude 12°46′N and 80°18′E longitude is a vast sheet of water, 250 hectares in extent. It is located 36 km south of Madras city close to the Madras-Thanjavur coastal road. No rivers join the backwaters but during north-east monsoon period, surplus water from many irrigation tanks in Saidapet and Chingleput taluks flow into it, as a result of which the barmouth opens and there is free exchange of sea water. Apart from this, there is considerable flow of water from the Palar estuary and the Marakkanam salt swamp during the rainy season through the Buckingham canal which passes through these backwaters.

The backwaters extend 15 km in North-South direction with a maximum width of 300 m and depth of 3.5 m, while the average depth is 1.2 m. During summer months, the entire column of water is reduced to isolated ponds, puddles and canals. Most of the backwater banks is sandy. Many areas are used for salt production.

The barmouth of the backwaters is 150 m long during floods in October-December period which gradually constricts with cessation of flow of freshwater and completely closes by June each year to reopen again only during the next monsoon floods. The barmouth is fully sandy and about 1.5 m deep. The maximum tidal amplitude is 0.5 m and its effect is felt upto 3.0 km interior when the barmouth is fully open.

Materials and Method

Rearing of prawn juveniles of 25.0 mm-35.0 mm sizes was done in cages of 5 × 2 × 1 m made of lunite plastic screening of 16P (36 mesh/cm). Some of these cages were fixed to poles driven close to the shore in Kovalam backwaters in places where the depth of water was 1.5 m. Some cages were suspended from rafts made of casurina poles kept buoyant by tying to air tight drums (either plastic or metal) and anchored in places where the water depth ranged between 2.5 and 3.5 m at low tide. Rearing of prawns was also done in double-layered cages of the same sizes as mentioned above, but with a horizontal partition provided in the middle with the same construction material so that prawns could be stocked in both the layers. Feeding for the lower layer was effected by providing a funnel-shaped entrance to this layer alone from the top cutting through the middle partition. Floating pen having 8 × 4 × 1.50 m size was also used for prawn culture in the backwater suspended with the help of a raft constructed by using casurina poles and barrels. Apart from the natural food that entered the cages from the environment, feeding was done once a day in the evening, using a variety of artificial feeds, flesh of *Tilapia*, clam meat and pellets made out of minced trash fish, tapioca flour, rice bran, groundnut oilcake and dried algae. Frog flesh waste was also used as one of the sources of animal protein and for providing a stable binding agent. Pelletisation was done in a motor-driven pelletiser. These pellets remained stable in water for 18 to 24 hours and were well accepted by the prawns. Culture cages were cleaned once in a week to remove the debris, weeds and fouling organisms deposited in the cages. Varying stocking densities were tried and the quantum of feed also varied proportionately. In earlier stages of rearing, a higher percentage of feed at the rate of 30 to 100% of body weight was supplied but when the prawns grew bigger, the ration of supplemental feed was maintained at 5 to 15% of the body weight.

Recording of environmental parameters such as surface water temperature, salinity, dissolved oxygen and pH was made throughout the period of observation.

Seed surveys were carried out at four centres, three in Kovalam backwaters and one in the temporary pools formed adjacent to the sea shore during high tide especially during full-moon and new moon period. Velon screen drag nets operated by two persons were used for the seed survey.

Results and Discussion

Environmental parameters

Hydrological parameters during the period of observation (Table 1) indicated the suitability of site for shrimp farming. Nature of the barmouth and the inflow of freshwater through the Buckingham canal during the monsoon months greatly influence the hydrological conditions, especially the salinity.

TABLE 1. *Details of physico-chemical conditions of the Kovalam backwaters near the culture site*

Parameters	1975-76		1976-77		1977-78		1978-79	
	Mini.	Max.	Mini.	Max.	Mini.	Max.	Mini.	Max.
Surface water temperature (°C)	24.8	32.5	25	31.5	27	31	26	32
pH	7.8	8.5	7.9	8.35	7.8	8.4	8.6	8.7
Dissolved oxygen (ppm)	2.4	13.4	3.4	10.2	3.6	9.6	3.6	7.6
Salinity (ppt)	8.14	41.5	1.5	37.9	1.5	39.1	1.4	40.8
Phenolphthalein Alkalinity (ppm)	6	22	4	16	4	16	3	14
Methylorange alkalinity (ppm)	64	124	54	123	50	129	64	116
Carbondioxide (ppm)	Nil	Nil	Nil	Nil	Nil	1	Nil	Nil

TABLE 2. *Species-wise drag net catch of postlarvae/juveniles (Per net per hour) in the Kovalam backwaters during the years from* 1975-76 *to* 1978-79

Months	1975-76			1976-77			1977-78			1978-79		
	Penaeus indicus	*Penaeus monodon*	*Metapenaeus* spp.	*Penaeus indicus*	*Penaeus monodon*	*Metapenaeus* spp.	*Penaeus indicus*	*Penaeus monodon*	*Metapenaeus* spp.	*Penaeus indicus*	*Penaeus monodon*	*Metapenaeus* spp.
April	150	—	200	240	—	70	120-258	—	Neg.	40-180	—	48-82
*May	225	—	225	252	—	336	2800-4500	—	20-45	60-214	—	4-32
*June	200	—	120	1200	—	90	378	—	12	530-1000	—	30-48
*July	175	—	110	144	—	298	120-180	—	36-48	150-280	—	41-82
*August	800	—	190	252-3810	—	188-280	16-87	—	100-1585	25-350	—	18-24
*September	750	—	200	1240-2940	—	100-340	12-24	—	120-1200	600-1000	—	120-285
*October	1100	—	500	1080-2516	42	180-1320	750-1000	—	266-1200	60-500	—	42-59
November	2215	2600	1110	824	84-300	70-140	100-120	100-250	150-205	34-40	333-999	102-182
December	2090	1350	900	30-260	90-480	240-320	50-108	75-300	38-45	66-133	39-500	111-179
January	700	400	790	40-240	40-360	180-270	30-110	21-100	33-36	120-440	10-50	42-63
February	225	—	395	30-4380	—	28-62	168-3020	—	32-76	50-3000	—	12-39
March	200	—	192	172-2341	—	18-56	62-300	—	12-32	12-1500	—	142-315

* Prawn seed available only in temporary pools formed adjacent to sea at Kovalam.

During the monsoon months (October-November) the salinity ranged from 1.5‰ to 8.14‰. The barmouth is open only during the monsoon months when the freshwater rushes into the backwater. Maximum salinity from 37.9‰ to 41.3‰ was recorded during July-August.

Dissolved oxygen content ranged from 2.4 ppm. to 13.4 ppm. during the four-year period. The wide fluctuations in the level of dissolved oxygen content did not affect the growth of prawns.

The pH values did not show great fluctuations and it was always on the alkaline side, which is the ideal condition for prawn culture.

Carbondioxide was absent throughout the period of observation except for a few weeks and that too was not over 1 ppm.

Lowest surface water temperature fluctuated between 24.8°C and 27°C during December-January months and the highest of which ranged from 31°C to 32.5°C during April-May. There were no wide fluctuations in the lowest and highest temperatures between the four-year period of observations.

Shrimp seed resources

A perusal of Table 2 indicates that recruitment of prawn postlarvae takes place during the period when the backwater was in communication with the sea. Thus the recruitment generally is restricted to a period of 6-7 months in a year.

Among the commercially important species of prawns, seeds of *Penaeus indicus* were available throughout the period of six months, in all the three centres of Kovalam backwaters when the estuary was open to the sea. But the peak season appeared to be October and February to March extending upto April depending upon the nature of barmouth, whereas in the temporary pools formed adjacent to seashore, during hightides especially during new-moon and full-moon periods. *P. indicus* seeds were available throughout the year with peak periods in May-June, September-October and February-March.

Postlarvae and juveniles of *P. monodon* were available in the backwaters only in three months from November to January with the peak in November and December. In the temporary pools, *P. monodon* seeds were collected only in lesser numbers.

Though there are two peak periods for both *P. indicus* and *P. monodon* seed availability (Rao, 1980), due to the shorter period of opening of the barmouth only one season could be observed as far as Kovalam backwater is concerned.

Metapenaeids were represented by *Metapenaeus monoceros* and *M. dobsoni*. Peak periods of their availability varied from year to year.

SHRIMP CULTURE EXPERIMENTS

Results obtained from the shrimp culture experiments in different enclosures are given in Tables 4 to 9. As many as 25 to 46 experiments were conducted (Table 4) using *P. indicus*, *P. monodon* and *M. monoceros* seeds during the period from 1975 to 1979.

During 1975-76 only *P. indicus* seeds were used for culture experiments. A total of 33 experiments were conducted in cages of 10 m^2 at two stocking densities i.e., 50 and $75/m^2$ for a period of 91-100 days. First three types of feeds mentioned in Table 3 were used at different rates mentioned thereunder. Production rates ranged from 50 to 200 gm/m^2. In 91 days shrimps stocked at the rate of $50/m^2$ attained an average size and weight of 75.7 mm and 2.8 gm respectively (Table 5) whereas shrimps stocked at the rate of $75/m^2$ attained only 64.2 mm and 1.8 gm in 100 days.

TABLE 3 *Types of supplementary feeds used and rates of feeding in prawn culture experiments during* 1975-1979

Type of feed	Rate of feeding (to the total body weight(%))		
	1st Month	2nd Month	3rd Month Onwards
Flesh of *Tilapia*	100	50	25
	80	40	20
	40	20	10
Flesh of clam, *Meretrix casta*	100	50	25
	80	40	20
	40	20	10
	30	15	5
Pellet A : fish meal : shrimp head meal : rice bran (2 : 1 : 1) and 5% rice flour	50	30	15
Pellet B : fish meal 35%, groundnut oilcake 20%, rice bran 35%, maida 10%, few drops of citric acid	50	30	15
	30	15	5
Pellet C : frog flesh waste 58%, groundnut oil cake 4%, rice bran 20%, tapioca powder 1%, urea and polyphosphate 0.5%, shrimp head meal 6%, algal powder 6%, salt 1.5% and few drops of citric acid	40	20	10
	30	15	5
Pellet D : fish meal 35%, rice bran 35%, tapioca powder 25%, algal powder 4%, shellgrit 1% and *Agar* 15 gm/kg.	50	30	15
	40	20	10

TABLE 4. *Details of prawn culture experiments conducted in different types of enclosures for four years from 1975-76 to 1978-79*

Year	Species stocked	Description of cage	Number of cages used	Stocking density per cage	Rate of stocking per m²	Duration of experiment (days)	Survival rate %	Production in Kg.	Rate of production per m² (gm)
1975-76	*Penaeus indicus*	10 m² rectangular fixed cage	33	500-750	50 to 75	90-100	83-100	0.500 to 2.000	50 to 200
1976-77	*Penaeus indicus*	-do-	26	240-400	30 to 100	90-120	37-100	0.510 to 3.195	50 to 350
	Penaeus monodon	-do-	6	100-200	10 to 20	106	87-100	1.235 to 1.920	124 to 192
1977-78	*Penaeus indicus*	-do-	20	250-1000	25-100	61-125	40-100	0.850 to 3.900	85 to 390
	Penaeus indicus	10 m² floating cages	16	400-600	40-60	56-92	20-100	0.700 to 2.500	70 to 250
	Penaeus indicus & *Penaeus monodon*	10 m² fiixed rectangular cage	3	60-80 / 20-40	6 to 8 / 2-4	66 / —	95-100 / 66.7-95	0.490 to 0.600 / 0.145 to 0.250	49 to 25 / 14.5 to 25
	Metapenaeus monoceros	-do-	2	1000	100	84	20 to 50	0.300 to 0.750	33 to 750
1978-79	*Penaeus indicus*	-do-	10	500-1000	50 to 100	87-123	50 to 100	1.300 to 3.450	130 to 345
	Penaeus indicus	10 m² double layered cage	1	500 / 500	50 / 50	89 / —	76 / 92	2.000 to 2.100	200 / 210
	Penaeus indicus	40 m² floating pen	1	3000	750	115	85.33	13.800	345
	Penaeus indicus	10 m² floating cage	8	500	50	100-156	54.2—99	1.900—3.800	190 to 380
	Penaeus monodon	10 m² rectangular fixed cage	5	60	6	90		1.100-1.250	110 to 250

TABLE 5. *Growth and survival rates of* Penaeus indicus *cultured in 10 m^2 cages at various stocking densities with different types of feeds during 4 years from 1975-76 to 1978-79*

Year	Number stocked	Rate of stocking per m^2	Mean length at the time of stocking (mm)	Mean weight at the time of stocking (gm)	Duration of experiment (days)	Mean length at the time of harvest (mm)	Mean weight at the time of harvest (gm)	Number of prawns harvested	Survival rate (%)	Quantity of prawns harvested (kg)	Production rate per Sq. metre (gm)	Types of feed used
1975-76	500	50	26.3	0.09	91	75.7	2.8	325	65	0.910	91	Flesh of clam
	500	50	26.3	0.09	91	70.4	2.2	500	100	1.100	110	Pellet A
	750	75	43.2	0.37	101	64.2	1.8	405	81	0.730	730	Flesh of clam
	750	75	43.2	0.37	101	66.2	1.2	440	88	0.528	52.8	Pellet A
1976-77	400	40	30.56	0.2	120	105.32	8.8	350	87.5	3.035	303	Flesh of Tilaapi
	400	40	48.2	0.73	120	110.38	8.8	356	89	3.195	319.5	Flesh of clam
	400	40	30.56	0.2	120	89.76	4.4	326	81	1.430	143	Pellet B
	300	30	30.56	0.2	120	92.27	4.6	257	85.67	1.195	119.5	Flesh of clam
	300	30	32.28	0.24	90	70.72	4.36	111	37	0.510	51	No feed
1977-78	400	40	26.97	0.15	106	89.5	5.6	394	89.5	1.820	182	Flesh of clam
	500	50	16.64	0.04	126	95.2	5.5	350	70	1.925	192.5	-do-
	600	60	16.74	0.05	126	98.6	6.1	140	23.33	0.847	84.7	-do-
	700	70	17.08	0.05	126	91.12	5.6	700	100	3.900	390	-do-
1978-79	500	50	31.18	0.12	100	103.28	7.68	495	99	3.800	380	Pellet C
	500	50	31.18	0.12	120	96.4	6.03	500	100	3.150	315	Flesh of clam
	500	50	33.9	0.19	100	87.739	5.00	446	89.2	2.230	2230	Pellet D

TABLE 6. *Growth and survival rates of* Penaeus monodon *cultured in* 10 m^2 *cage at various stocking densities during* 1975-76 to 1978-79

Year	Number stocked	Rate of stocking per m^2	Mean length at the time of stocking (mm)	Mean weight at the time of stocking (gm)	Duration of experiment (days)	Mean length at the time of harvest (mm)	Mean weight at the time of harvest (gm)	Number of prawns harvested	Survival rate (%)	Quantity of prawns harvested (kg)	Production rate per Sq. metre (gm)	Type of feed used
1976-77	100	10	22.45	0.151	106	114.88	13.0	100	100	1·235	123.5	Flesh of clam
	150	15	20.6	0.05	106	106.28	9.6	150	100	1.440	144	-do-
	200	20	51.56	1.0	106	107.28	10.8	194	97	1.920	192	-do-
1977-78	100	10	50·33	1.125	92	99.56	8.0	100	100	0.800	80	Flesh of clam
	50	5	54.54	3.00	92	128.7	18.0	50	100	0.900	90	-do-
1978-79	60	6	45.267	1.02	92	124.5	19.492	59	98.33	1.150	115	Pellet C
	60	6	71.2	3.3	95	128.7	20.00	37	67.67	0.740	74	Flesh of clam
	60	6	32.56	0.096	100	84.54	9.26	23	38.33	0.240	24	No feed

TABLE 7. *Growth and survival rates of* Metapenaeus monceros *cultured in* 10 m^2 *cages during the year* 1977-78

Year	Number Stocked	Rate of stocking per Sq. metre	Mean length at the time of stocking (mm)	Mean weight at the time of stocking (gm)	Duration of experiment (days)	Mean length at the time of harvest (mm)	Mean weight at the time of harvest (gm)	Number of prawns harvested	Survival rate (%)	Quantity of prawns harvested (kg)	Production rate per Sq. metre (gm)	Type of feed used
1977-78	1000	100	14.3	0.18	84	64.3	1.5	500	50	0.750	75	Flesh of Meretrix
	1000	100	13.88	0.18	84	60.52	1.65	200	20	0.330	33	No feed

No marked difference in terms of growth was achieved with different types of supplementary feeds. In the former experiment where clam meat was given as supplementary feed cent per cent survival was achieved.

Both *P. indicus* and *P. monodon* seeds were reared in cages during the year 1976-77. Of the 46 rearing experiments conducted on *P. indicus* most of them were at 30-40/m² stocking densities. Three types of feeds as mentioned in Table 5 were tried. Production rates ranged from 50 to 319 gm/m² with 37-100% survival rates. High growth (110.4 mm), production (319.5 gm) and survival rates (89%) were achieved at a stocking density of 40/m² in 120 days with flesh of clam as supplementary feed. The prawns were fed at the rate of 40%, 20% and 10% of their total body weight for the first, second and third months of rearing respectively.

At the stocking density of 20/m² best production rate of 192 gm/m² with 97% survival was obtained in 106 days for *P. monodon*. Poor survival rates due to absence of supplementary feed in some of the cages resulted in lesser production of 50 gm/m².

Two types of enclosures (ordinary fixed cages and floating cages of 10 m² size) were used to rear *P. indicus* during the year 1977-78. Twenty experiments in ordinary cages and 16 experiments in floating cages with stocking densities at the rate of 25 to 100/m² and 40-60/m² respectively were conducted for 61 to 125 days and 56 to 92 days period. Flesh of clam, flesh of *Tilapia*, Pellet-B and Pellet-D were the four types of feeds used for the rearing experiments. Production rates in ordinary cage ranged from 85 gm to 295 gm/m² and in the floating cages it ranged from 129 to 390 gm/m². Survival rates were found to be 37 to 82%. Generally growth and survival were better in the case of shrimp cultured in floating cages. Flesh of clam and fish given at 30%, 15% and 5% to the total body weight during first, second and third months respectively was found to be comparatively better ration for caged shrimps.

Two species of penaeid prawns, *P. indicus* and *P. monodon* were cultured together in different stocking densities (6-8/m² and 2-4/m²) in three cages (Table 4) with clam meat as feed. The production rates of *P. indicus* after 66 days ranged from 49 to 60 gm/m² and that of *P. monodon* from 14.5 to 25 gm/m². In this mixed culture experiment the growth rate of *P. indicus* was comparatively faster.

In two experiments on culture of *M. monoceros* with/without supplementary feed conducted during 1977-78, the growth and survival rates were found to be very poor. Production rates were 33 and 75 gm/m² respectively in the case of shrimp reared with and without supplementary feed (Table 7).

During the year 1978-79, four types of net enclosures were tried for the rearing of *P. indicus* and *P. monodon*. Ten experiments were conducted on rearing of *P. indicus* in 10 m² ordinary cages (Pl. I A), 8 in floating cages (Pl. I B), one in floating pen (Pl. I C) and one in double layered cage (Fig. 1). Production rates of these experiments are given in Table 9.

In ordinary cage, average growth was 60.7 mm and 4.7 gm in 87 to 123 days. Rate of production raged from 130 to 345 gm/m². Average production was found to be 236 gm/m². Feeding was done with flesh of clam and *Tilapia*, Pellet-C and Pellet-D at different rates. Comparatively maximum growth and survival rates were obtained from Pellet-C at the rate of 30%, 15% and 5% for the three months' period (Table 8).

In contrast to this, in eight experiments conducted in floating cages, with uniform density of 500/m² for a period of 100 to 156 days, an average growth of 69 mm/7 gm was obtained with an average production of 281 gm/m²

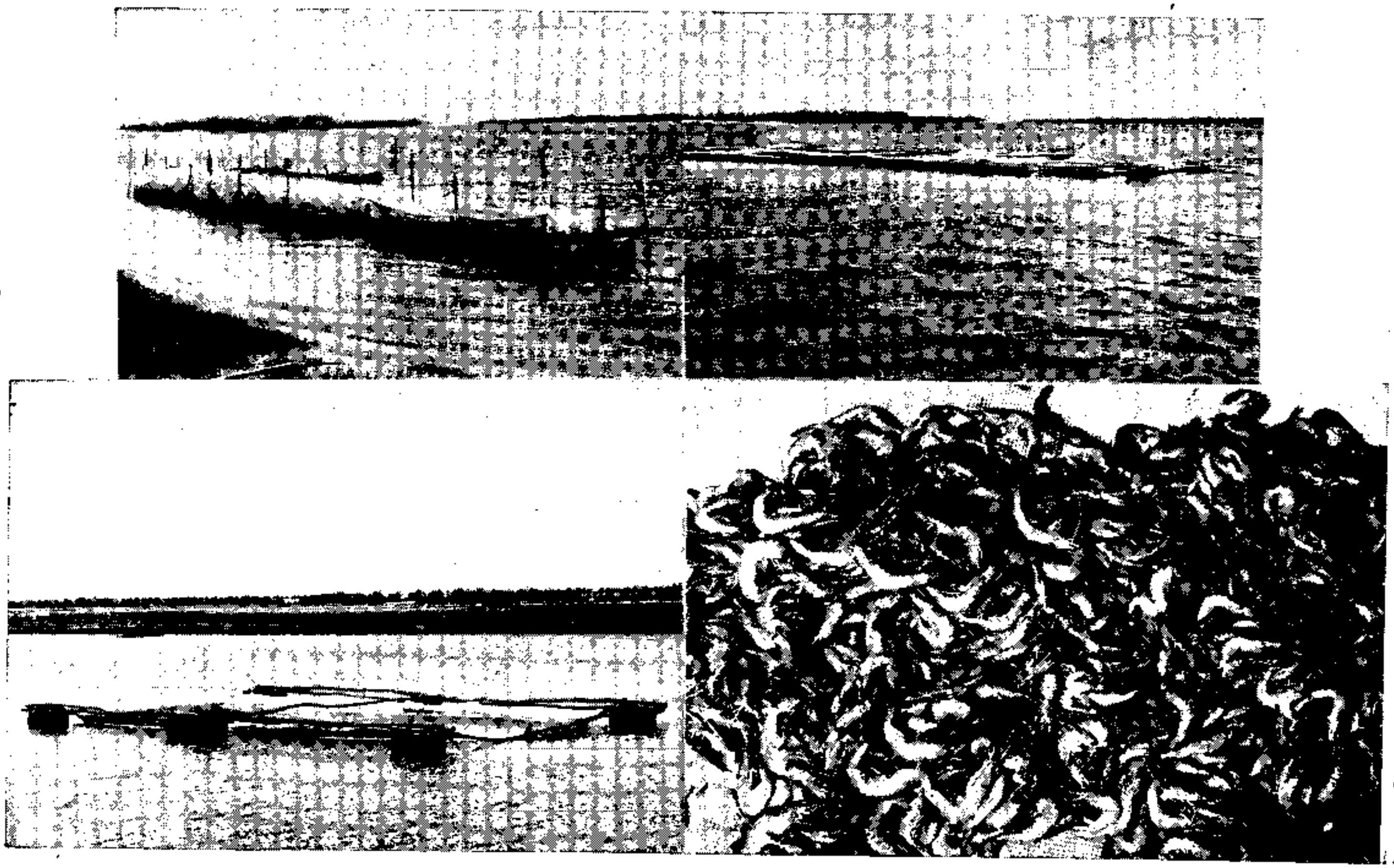

PLATE I. A. Battery of 10 m² fixed cages, B. Three sets of 10 m² floating cages suspended in Kovalam backwaters, C. A 40 m² floating pen suspended, and D. Prawn harvest from a 10 m² cage.

which was 45 gm more than the production obtained in ordinary cages.

In a floating pen of 8 × 5 × 1.50 m size, made up of knotless webbings, *P. indicus* juveniles were reared at 75/m². The survival rate was 85% and the weight increment was 5.3 gm in 115 days. Pellet-C was used at 40%, 20% and 10% to the total body weight during the first, second and third months respectively as supplementary feed.

P. indicus cultured in double layered cage at 50/m² in each layer for 89 days yielded a production at the rate of 200 gm and 210 gm/m² in the top and bottom layers respectively.

pellet feed (Pellet-C), rate of feeding and improvements in cage designs. Of the six types of feeds mentioned in Table 3, flesh of clam and *Tilapia* were found to be good in the beginning and after compounding Pellet-C by using frog flesh waste as the main ingredient it was found to be more acceptable by the shrimp. Table 8 shows the conversion rates obtained from different types of feed. It can be seen from the table that Pellet-C was better than other feeds giving a conversion rate of 3.01 and 5.87 for *P. indicus* and *P. monodon* respectively.

Observations revealed that the average culture peirod of prawn has to be restricted to 120 days, as keeping the culture stock inside the cage

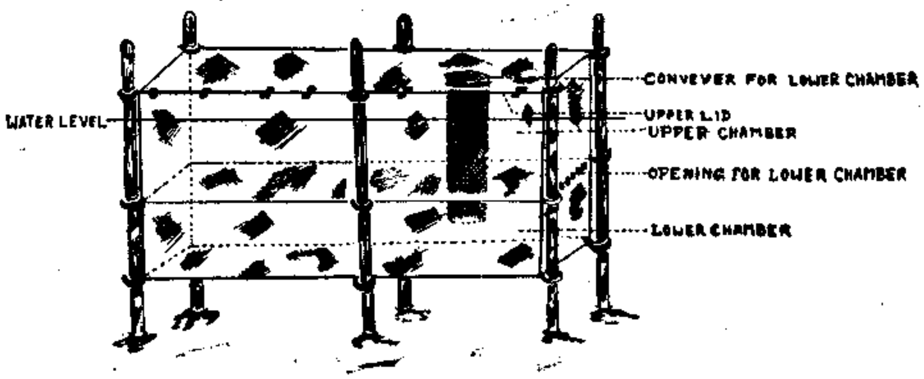

Fig. 1. A 10 m² double layered cage.

P. monodon seeds were cultured in five 10 m² ordinary cages at the rate of 6/m² for a period of 90 days with feed Pellet-C and flesh of clam, and an average production of 85.2 gm/m² was obtained. Growth and production was comparatively better in the case of prawn fed with Pellet-C at 30%, 15% and 5% to the total body weight for three months period respectively.

It can be seen from Table 4 that production rates increased from 1975-76 to 1978-79 which was due to the evolution of better types of for longer periods has slowed down the growth and affected the survival rates.

The results obtained showed that growth and production of shrimps were comparatively better in the culture cages suspended from floating rafts in 3 to 4 metre deep portion of the backwaters. 40 m² floating pen made out of knotless webbings also gave better results. Similarly the double layered cage not only provided additional rearing space, but also gave still higher production of 410 gm/m².

TABLE 8. *Production and conversion obtained in cage culture of prawns with different types of feed*

Species	Number stocked	Rate of stocking per m^2	Type of feed	Total quantity of feed given (kg)	Total increase in weight (kg)	Conversion Feed : Prawn
Penaeus indicus						
1976-77	400	40	Flesh of clam	34.700	2.100	16.53 : 1
	400	40	Flesh of Tilapia	52.000	2.955	17.60 : 1
	400	40	Pellet-B	50.00	1.350	37.04 : 1
1978-79	500	50	Pellet-C	15.350	3.750	4.09 : 1
	500	50	Flesh of clam	18.300	3.100	5.903 : 1
	500	50	Pellet-D	16.500	2.135	7.704 : 1
Penaeus monodon						
1976-77	100	10	Flesh of clam	10.360	1.184	8.75 : 1
1978-79	60	6	-do-	5.100	0.542	9.446 : 1
	60	6	Pellet-C	6.110	1.039	5.87 : 1
Metapenaeus monoceros						
1977-78	1000	100	Flesh of clam	12.000	0.570	21.05 : 1

TABLE 9. *Average production of* Penaeus indicus *in different type of enclosures in* 100 to 120 *days of rearing during the year* 1978-79

Type of cage	Area	Number stocked	Production (Kg)	Rate of production per m^2 (gm)	Average size of prawns at the time of harvest (mm)
Ordinary cage ..	5 × 2 × 1 m (10 m^2)	500	2.360	236	97.61 mm/6.3 gm
Floating cage ..	5 × 2 × 1 m (10 m^2)	500	2.810	281	106.15 mm/7.73 gm
Double layered cage ..	5 × 2 × 1 m (10 m^2)	500 / 500	2.000 (top) / 2.100 (bottom)	200 / 210 (410)	Toplayer 91.86 mm/5.26 gm Bottom layer 85.63 mm/4.56 gm
Floating pen ..	8 × 5 × 1.50 m (40 m^2)	3000	13.800	345	94.2 mm/5.4 gm

Compared to the growth rates of *P. indicus* and *P. monodon*, growth of *M. monoceros* was poor and it may be assumed that growing them in cages would not yield better result.

Heavy feeding with supplementary feeds at rates about 30%, 15% and 5% to the total body weight for the three months period resulted in wastage of feed and accordingly poor conversion rates were obtained in the beginning of cage culture experiments during the year 1976-77.

Physico-chemical parameters of the backwaters were found to be favourable for the growth and survival of prawns. Better growth was noticed during November and December when the salinity was between 19‰ and 23‰.

Average estimated growth of *P. indicus* in most of the cages was found to be 18.5 mm/month and 29.8 mm/month in 120 and 90 days rearing. Even at this high stocking density, the growth compares well with the growth of the species in the natural environment of the Kovalam backwater, where the monthly growth ranged from 15 mm to 28 mm (C.M.F.R.I., 1975).

From the overall analysis of the results of the prawn culture experiments conducted during the years 1975-1979 it may be assumed that the nylon cages could be successfully used for raising two crops of medium sized prawns with suitable artificial feed and could give an average annual production of 736 gm/m^2 in two crops.

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OBSERVATIONS ON THE CULTURE OF TIGER PRAWN *PENAEUS MONODON* FABRICIUS, IN BRACKISHWATER PONDS

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ABSTRACT

Experiments on the Culture of tiger prawn, *Penaeus monodon* were conducted in the brackishwater ponds in Santhome Fish Farm, Madras. The size of the ponds ranged from 0.1 to 1.14 ha. After removing the predatory fishes, the ponds were manured with inorganic fertilizers. Juveniles of tiger prawn ranging from 20.0 to 45.0 mm in length were stocked at densities ranging from 25,000 to 40,000/ha and reared for a period of 90 days. No supplementary feed was given to the prawns. But fertilizers were applied at regular intervals.

The prawns attained an average size of 154.5 mm and a weight of 25.7 g in 90 days at a stocking density of 25,000/ha and 129.5 mm and 14.4 g in 90 days at a density of 40,000/ha. Survivals of prawns varied from 81.02 to 86.2%. Maximum production of 521.2 kg/ha in 90 days was achieved at a stocking density of 25,000/ha and the minimum of 496.5 kg/ha in 90 days was obtained at a density of 40,000/ha.

INTRODUCTION

AMONG the penaeid prawns that are available in the seas of India, the tiger prawn *Penaeus monodon* Fabricius is considered to be outstanding in its adaptability to culture, general hardiness and growth rate. Thus it becomes the most favourable species for culture in brackishwater ponds. Studies were initiated from 1977 onwards at the Tamil Nadu Sub-Centre of the All India Coordinated Research Project on Brackishwater Fish Farming at Madras on the culture of this species in brackishwater ponds. The details of some of the experiments on the culture of tiger prawn, *P. monodon* conducted during 1977-1979 are embodied in the present communication.

The authors are thankful to Shri C. Chellappan, I.A.S., Director of Fisheries, Government of Tamil Nadu and Dr. A. V. Natarajan, Director, Central Inland Fisheries Research Institute, Barrackpore and Coordinator of the Project for their encouragement and guidance in the study.

MATERIALS AND METHODS

The experiments each of 90 days duration were conducted in two 0.1 ha (ponds 6 & 8) and one 1.14 ha (Pond 1) ponds at the Santhome Brackishwater Fish Farm, Madras. The height of the water column in the ponds ranged from 0.6 to 1.2 m during the period of study. Tidal water was let into the ponds by operating a sluice gate for 3 to 4 days during each spring tide, through a creek which originates from the Adyar estuary near its mouth.

Before stocking, the water level of the ponds were reduced to the lowest level (0.3 to 0.4 m) and the predatory and weed fishes were removed by thorough netting with fine meshed cast nets and drag nets. The bottom soil of the ponds was raked thoroughly to release the abnoxious gases. Then the ponds were fertilized with urea and superphosphate in the ratio of 4 : 1 respectively at a rate of 100 kg/ha. A week after the application of fertilizers, water level of the pond was increased to 0.7 to 0.8 m by allowing fresh tidal flow.

Juveniles of *P. monodon* ranging from 20.0 to 45.0 mm were collected from the nearby Adyar estuary and Kovelong backwaters and transported to the farm where they were conditioned overnight in hapas fixed in the experimental ponds. Next morning, healthy young ones were selected, counted and released. The details of stocking are shown in Table 1.

The growth of prawns was recorded by monthly sampling. Physico-chemical conditions of the culture ponds (Table 3) were recorded once in a week. The prawns were reared for 90 days. Water level of the ponds was reduced to the minimum and then the prawns were harvested by repeated thorough netting by cast nets.

Results and Discussion

The monthly fluctuations in water temperature, salinity and pH of the ponds were not wide

Table 1. *Details on the density, number, size and weight of prawns stocked*

	Pond		
	1	6	8
Area of the pond (ha)	1.14	0.1	0.1
Date of stocking	12.12.78	1.10.77	21.11.77
Stocking rate/ha	25000	40000	25000
Average size (mm)	35.5	36.8	34.5
Average weight (g)	0.45	0.47	0.42

Table 2. *Fertilizers applied during rearing*

Pond	Quantity applied in kg		Frequency
	urea	superphosphate	
1	72.96	18.24	4 instalments (20th, 40th, 60th and 80th day after stocking)
6	6.4	1.2	2 instalments (30th and 60th day after stocking)
8	6.4	1.6	-do-

During rearing, fertilizers, urea and superphosphate, in the ratio of 4 : 1 were applied in all the ponds at regular intervals as shown in Table 2.

(Table 3). Similarly there were not much variations in those conditions from one pond to the other. Monthly dissolved oxygen values of the ponds 6 and 8 ranged from 3.64 to 7.8

and 3.4 to 7.29 ppm. respectively during the period of rearing. But in Pond 1, a maximum value of 8.21 ppm. was recorded in the first month of rearing which came down to the minimum value of 1.0 ppm. during the last month of rearing. The low values of dissolved oxygen in Pond 1 were due to the lack of proper tidal flushing.

size and weight (129.5 mm/14.4 g) were recorded in Pond 6 at a higher stocking density of 40,000/ha. The poor growth appeared to be mainly due to high stocking density. The growth pattern of prawns in the three experimental ponds are shown in Fig. 1. In all the ponds the growth of prawns was almost uniform in the first month and in the second and

TABLE 3. *Ranges of important Physico-chemical conditions of the experimental ponds*

	Pond		
	1	6	8
Water temperature (°C)	24.6-32.8	24.2-31.7	23.9-32.5
pH	7.8-8.4	7.9-8.4	7.6-8.4
Salinity (ppt)	8.86-16.27	11.74-16.39	11.60-19.48
Dissolved oxygen (ppm)	1.0-8.21	3.64-7.8	3.4-7.29

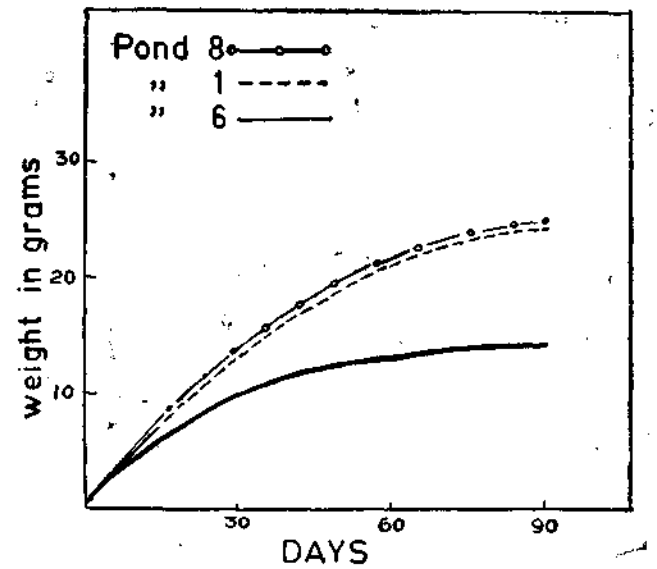

Fig. 1. *Growth of tiger prawn in three experimental ponds.*

The results of rearing are given in Table 4. It will be seen from the Table that the final size and weight attained by the prawns were almost equal in ponds 1 and 8 at the stocking densities of 25,000/ha. Relatively poor final

third months of rearing growth continued to be uniform in ponds 1 and 8. But in pond 6, growth slowed down from the second month onwards.

Survival of prawns was almost uniformly higher (above 80%) in all the ponds and a maximum of 86.2% was recorded in pond 6.

Almost identical production of prawns 496.5 kg/ha and 498.2 kg/ha was obtained in ponds 6 and 1 respectively. Slightly better yield of 521.2 kg/ha was recorded in pond 8. In general the production in the present experiments under simple management could be considered satisfactory.

TABLE 4. *Growth, survival and production of tiger prawns in the experimental ponds*

	Pond		
	1	6	8
Numbers recovered	23092	3448	2028
Average size (mm)	152.5	129.5	154.5
Average weight (g)	24.6	14.4	25.7
Percentage of recovery	81.02	86.2	81.12
Actual quantity harvested (kg)	567.94	49.65	52.12
Production kg/ha/90 days	498.2	496.5	521.2

Chen (1976) reported a growth rate of 40.0 g in 90 days rearing under comparatively lower stocking densities of 5000 to 8000/ha in Taiwan where prawns and *Chanos* were cultivated together. At a stocking rate of 20,000 tiger prawns/ha Sundararajan *et al.* (1979) observed an average weight of 32.26 g in 80 days. Growth of prawns in the present experiments is comparatively lower at densities of 25,000/ha and poorer in higher stocking density of 40,000/ha.

Higher survivals obtained in all the ponds suggest that survival was not influenced either by stocking densities or by comparatively sub-normal water conditions (low oxygen values) encountered in one of the ponds. It may be attributed that the absence of predators had contributed to the higher survival of prawns in all the ponds. This confirms the view of Krantz and Norris (1975) who had observed that survival of 60-80% was to be expected under suitable pond conditions of absence of predators, sub-optimal temperatures and salinities. Water temperature, pH and salinity of the experimental ponds were normal during the period of rearing. Even the low oxygen values recorded in pond 1 during the last month of rearing had not affected the survival of prawns. However, low oxygen values in pond 1 led to the infestation of peritrich ciliates (*Zoothamnium* sp. and *Epistylis* sp.) on prawns.

Under congenial conditions an yield of 514 kg/ha of tiger prawns in 80 days of rearing was achieved (Sundararajan *et al.*, 1979) at a stocking density of 20,000/ha from the 1.14 ha pond in Santhome Farm during 1977-78. The average weight of prawns obtained in this experiment was 32.26 g. Compared to the above results, an almost equal production ranging from 496.5 to 521.2 kg were obtained under stocking densities ranging from 25,000 to 40,000. But the final size and weight attained by the individual prawns was far from satisfactory.

It was emphasised (Anon, 1977) that prawns weighing 33 g and above (30 numbers head on/kg) fetch the maximum price in the export market. Cook (1976) observed that with only fertilization it could be possible to grow upto 400 kg of shrimps/ha/crop. He also observed that longer the culture period the more susceptible the crop was to natural calamities. Therefore the objective should be to get maximum production of reasonably larger size prawns in a shorter rearing period by resorting to judicial stocking and optimal fertilization. The results obtained indicate that high growth rate is always achieved at low stocking densities. The present experiments suggest that a stocking density of 20,000 number of *P. monodon*/ha (as observed by Sundararajan *et al.*, 1979) could be the optimum. With fertilization, an yield of 500 kg/ha of reasonably larger size prawns (30-35 g) could be achieved in 3-4 months rearing.

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EXPERIMENTAL STUDIES ON HIGH DENSITY, SHORT-TERM FARMING OF SHRIMP *PENAEUS INDICUS* IN A 'POKKALI' FIELD IN VYPEEN ISLAND, KERALA

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ABSTRACT

High density, short-term culture experiments on the shrimp *Penaeus indicus* were carried out by setting three identical enclaves (25 m^2 each) using plastic netting and bamboo stakes in a paddy-cum-prawn filtration field at Narakkal during January-April, 1979. Each of the enclaves was stocked with 500 juveniles of 24-48 mm length having a modal size of 36 mm and average weight of 272 mg. Feeding with ground-nut oil cake was done once daily at the level of 5% of the body weight of shrimps. The cultures were harvested after 4, 8 and 12 weeks when the survival rates of 85.2%, 81.85% and 65.0% respectively were obtained.

In the first harvest, shrimps measured 69-96 mm with a modal size of 84 mm and weighed 3.76 g on average. Those netted after 8 weeks had a length range of 75-108 mm with mode at 93.0 mm and average weight of 5.35 g which was 1.42 times greater than that of the preceding. Size range of shrimps in the third harvest shifted between 105 and 129 mm with 117 mm at the mode and had an average weight of 11.22 g i.e. 42.25 times greater than that of the initial stock. The total yields of 1.601, 2.186 and 3.646 kg realised from these cultures became equivalent to 640.0, 874.0 and 1458.0 kg/ha.

Since it is possible to take a minimum of two short-term crops of 12 weeks duration, it is reasonable to assume that at 80% harvesting efficiency, the production of about 1750 kg/ha of marketable shrimps valued at Rs. 35,000—could be possible from fertile 'Pokkali' fields of Kerala.

During the course of experiments the temperature, salinity, pH and secchi disc reading of the field varied between 28.5 and 35.5°C, 17.2 and 26.15‰, 7.0 and 7.8 and 35 and 60 cm respectively. Diurnal oxygen level fluctuated between 1.0 ml/l and 6.8 ml/l.

Results of the present experiment indicate that *P. indicus* merits further field experiments as a species for short-term, high density farming.

INTRODUCTION

SHRIMP CULTURE practice in paddy fields (Pokkali) of Kerala locally known as 'Chemmeenkettu' and 'Bhasa-badha' fishery of West Bengal contributes the largest share in India's shrimp production from sources other than the usual capture fishery. Various aspects of these traditionally existing practices in India have been described by the earlier workers (Panikkar, 1937; Menon, 1954; Pillay, 1954; Gopinath, 1956; Kestevan and Job, 1957). Studies on the yield and economics of this fishery in Kerala (George *et al.*, 1968; George, 1974) have revealed that the successful commercial operation depends on the availability of four species of penaeid shrimps of which *Penaeus indicus* figures economically the most important though *Metapenaeus dobsoni* dominates the catches by weight. Recently, careful retrieval of the undersized juveniles of *P. indicus* from the day to day bag net catches and growing them again in the same field to marketable size was found to improve the yield considerably (Gopalan *et al.*, 1980).

Intensive cultivation of selected species of shrimps in closed systems though successfully experimented in many parts of the world (Foster and Beard, 1974; Shigueno, 1975, Neal, 1979) does not seem to suit the rural economic conditions of India as it involves heavy capital expenditure and high technical expertise. This has prompted us to investigate on how dense a viable short-term monoculture of *P. indicus* could be sustained within the carrying capacity of paddy field ecosystem. The present communication conveys the result of an experiment carried out in this line at Narakkal in Vypeen Island, Kerala in 1979.

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Materials and Methods

Experiments were carried out in a typical paddy-cum-shrimp culture field having an area of 4 hectares lying adjacent and connected by sluice gate with the outer bund canal at Narakkal, Vypeen Island. Three identical square enclaves (25 m^2) were made at three places in the field selected at random using plastic netting (2 mm mesh) and bamboo poles in such a way that the lower side of the netting penetrated the bottom and the upper side was well above the water level. The depth of the field was nearly 1m at high tide and 60 cm at low tide. After removing the algal patches and other obstacles the enclaves were fished using a cast net to eradicate the existing shrimps, fishes, crabs and such other organisms. The bottom of the enclave was made even except at the centre were an area of 1 m^2 was deepened further to get a depth of 1 m at low tide. The clogging of the netting by silt, slime and algal growth was periodically cleared by scrubbing with a brush.

Each of the enclaves was stocked with 500 healthy juveniles (2,00,000/ha) of *P. indicus* measuring 24 to 48 mm having a modal size of 36 mm and average weight of 272 mg which were carefully retrieved from filter bag nets as suggested by Gopalan *et al.* (1980). Feeding with ground-nut oil cake was done once daily at the level of about 5% of the body weight of shrimp. The cultures were completely harvested from the enclaves respectively after 4, 8 and 12 weeks of growth using cast nets and hand nets. The harvested shrimps were measured (from the tip of the rostrum to the distal end of telson) and weighed.

The normal fishery operations of the experimental field were going on in the traditional manner. Data on the catch composition, income and expenditure and other observations for the whole season were regularly recorded in a log book. The hydrographic conditions of the enclaves, open field and the feeder canal were monitored by adopting standard procedures (Strickland and Parson, 1965). The organic carbon content of the bottom sediment was analysed as suggested by El Wakeel and Riley (1957).

Result

The monthly averages of the hydrographic parameters monitored during the experimental period are presented in Table 1. In general the lowest temperature was in February (28-30°C) and the highest was in April (33.5-35.5°C). The temperature of the enclaves

TABLE 1. *Hydrographic parameters and organic carbon monitored during January-April, 1979 at Narakkal.*

Month	Temp. (°C)	Salinity (‰)	O_2 (ml/l)	pH	Secchi disc reading (cm)	Organic Carbon (%)
Culture enclave						
January 1979	32.6	17.30	2.6	7.2	60.0	0.84
February ,,	30.0	18.20	3.0	7.5	56.0	2.20
March ,,	34.5	22.05	4.7	7.8	40.0	2.88
April ,,	35.5	26.15	6.5	7.8	35.0	4.14
Open Field						
January 1979	32.5	17.20	2.6	7.2	60.0	0.85
February ,,	28.5	18.28	2.8	7.0	60.0	1.15
March ,,	33.0	21.33	5.0	7.4	55.0	1.75
April ,,	34.0	25.44	6.8	7.3	43.0	2.07
Outer bund canal						
January 1979	31.5	16.83	2.0	7.4	75.0	1.70
February ,,	29.0	18.82	1.6	7.0	70.0	1.85
March ,,	33.0	21.33	3.6	7.0	67.0	2.10
April ,,	33.5	25.81	2.6	7.2	58.0	2.64

TABLE 2. *Income and expenditure from the traditional method of shrimp culture during 1978-79 in a 4 hectare area of paddy field*

Item	Amount (Rs.)	Item	Amount (Rs.)
INCOME		EXPENDITURE	
Sale proceeds from shrimps		Lease amount and licence fee ..	15,750.00
1282.8 kg of *M. dobsoni* @ Rs. 3.25/kg		Sluice fabrication, installation and maintenance ..	1,000.00
39.75 kg of *M. monoceros* @ Rs. 8/kg ..	24,081.85	Preparation of field, dykes, canals, eradication of weeds and predators ..	300.00
782.19 kg of *P. indicus* @ Rs. 25/kg			
1.0 kg of *P. monodon* @ Rs. 40/kg			
Sale proceeds from fishes & other items		Workshed and canoes ..	550.00
3352 kg. of *Tilapia* @ Rs. 1.10/kg		Lamos, oil, bamboo/plastic screen ..	780.00
512 kg of *Etroplus suratensis* @ Rs. 5/kg ..	6,422.20	Nets and plastic basins ..	650.00
350 kg of misc. fishes @ Rs. 12/kg		Nursery, operation (including feed) ..	—
Total income ..	30,504.05	Contingencies ..	250.00
Income/ha. ..	7,626.01	Wages of workmen ..	3,650.00
Total Profit ..	803.95	Interest on capital @ 15% ..	1,146.50
Profit/hectare ..	200.99	Harvesting expenditure ..	5,623.60
		Total expenditure ..	29,700.10
		Expenditure per hectare ..	7,425.02

remained relatively higher throughout than that of the open field and outside. The salinity values showed more or less the same pattern of variation from January to April (16.83-26.15‰) in all the three areas with relatively higher values in the enclaves. As regards oxygen, higher values (2.6-6.8 ml/1) prevailed in tne open field than that of the enclaves whereas lower values (1.6-3.6 ml/1) were seen in the outside canal.

The diurnal 'oxygen pulse' of the enclaves has been graphically presented (Fig. 1). The lowest values (1.0-1.6 ml/1) of oxygen in the culture enclaves were noticed during the dawn hours and highest values (5.0-6.7 ml/1) in the afternoon. Values of temperature also showed a similar trend as regards minimum and maximum.

algal material were floating in the enclaves especially after 10th week.

The organic carbon values were the same (0.84%) in the enclaves and field during the beginning of experiment which later increased to 4.15% in the enclaves and to 2.05% in the open field. The organic carbon values showed less variations (2.0-2.64%) outside the field during the experimental period.

The size frequencies of surviving shrimps at the end of 4, 8 and 12 weeks and that of the initial stock are presented in Fig. 2. Of the 500 individuals stocked in each of the three enclaves 426 (85.2%), 409 (81.8%) and 325 (65.0%) individuals respectively could be harvested by the end of 4, 8 and 12 weeks (Fig. 2). In the first harvest shrimps measured 69-96 mm,

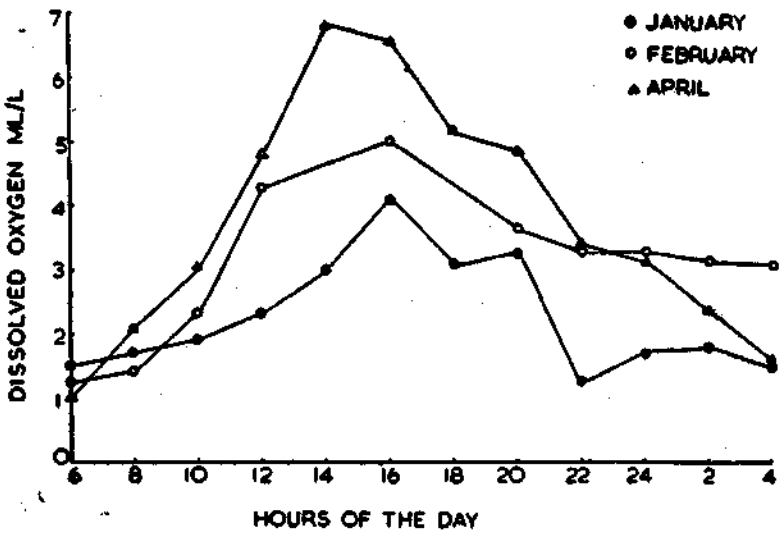

Fig. 1. Diurnal variation in dissolved oxygen in the monoculture enclaves during January-April 1979.

The pH values in all cases were 7 and above with higher values (7.5-7.8) in the enclaves during February-March. An increasing trend in turbidity of the enclaves as well as the open field is reflected in the secchi disc reading. Scum of waste comprising dead and decaying

with the modal size 84 mm and weighed 3.76 g on an average.

Those netted after 8 weeks had a length range of 75-108 mm with mode at 93 mm and average weight of 5.35 g which was 1.42 times greater than that of the preceding.

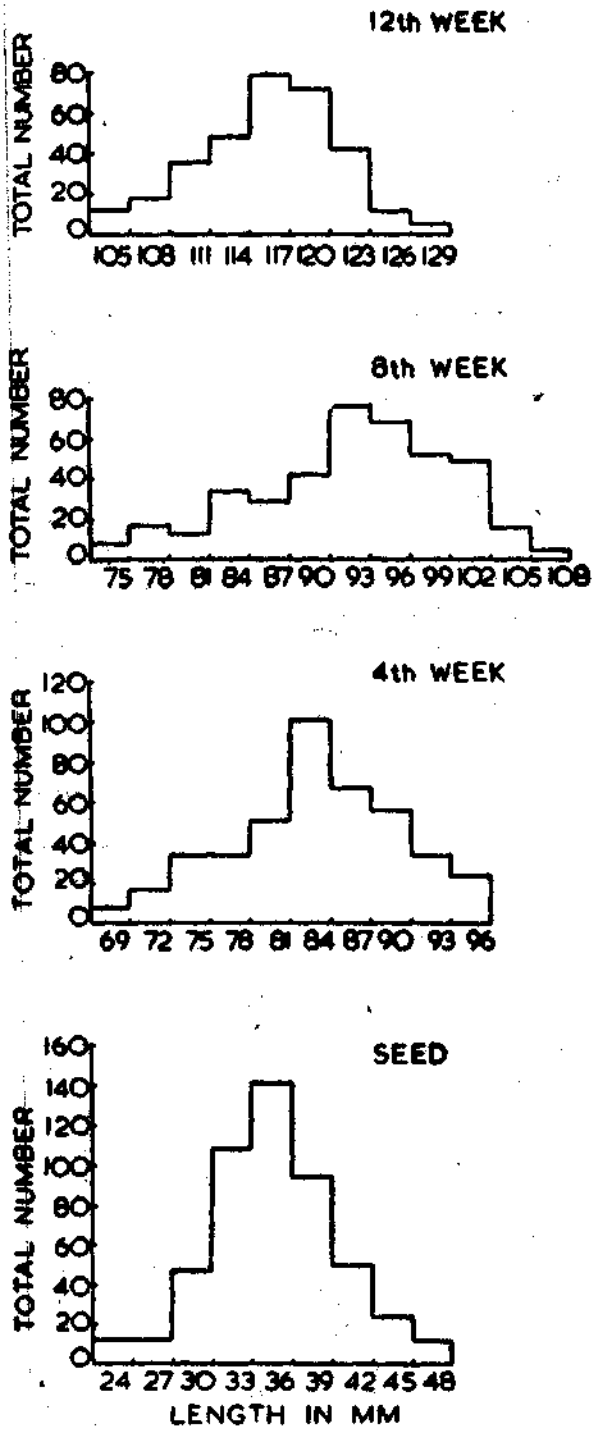

Fig. 2. The size frequencies of *Penaeus indicus* stocked and harvested after 4, 8 and 12 weeks by monoculture.

Size range of shrimps in the third harvest was 105-129 mm with mode at 117 mm and had an average weight of 11.22 g which was 42.25 times greater than that of the initial stock and 2.1 times more than the preceding.

Thus total yields of 1.601, 2.186 and 3.646 kg were harvested respectively from the three culture enclaves from an initial stock of 136.2 g in 25 m² area. This becomes equivalent to 640.4, 874.4 and 1458.4 kg/ha.

The growth rates of shrimps calculated from the first, 2nd and 3rd harvest respectively were 1.71, 1.02 and 1.13 mm per day.

The yield and economics of the experimental field which was operated in the traditional manner has been given (Table 2) for comparison with that calculated (Table 3) from the results of the monoculture of *P. indicus*. Only 50% of the production available during January-April is anticipated for the crop during October-January.

Of the 2105.74 kg of shrimps realised from the 4 ha field, *M. dobsoni* was 1282.8 kg, *P. indicus* 782.19 kg, *M. monoceros* 39.75 kg and *P. monodon* 1 kg. This works out to an average yield of 525.44 kg/ha.

The fish catch comprised mainly of 3352 kg of *Tilapia* and 512 kg of *Etroplus suratensis*. About 350 kg of miscellaneous species (crabs, Eels, *Ambasis* sp., *Etroplus maculatus*, *Barbus* sp., *Arius* sp., *Meglops* sp., *Gobius* sp.) were also caught from the same field. Thus the average yield of edible species other than shrimps was 1053.5 kg/ha, which makes a total yield of 1579.94 kg/ha.

Discussion

From the results of the present experiment it can be seen that *P. indicus* stocked under a density of 2,00,000/ha attained marketable size (11.22 g) after 12 weeks of growth with a fairly reasonable rate of survival (65.0%). The yields of 640.4, 874.4 and 1458.4 kg/ha which are obtainable respectively after 4, 8 and

12 weeks of monoculture of *P. indicus* suggest the advantages of short-term, high density farming of this species in 'Pokkali' fields. This when compared to the total yield of shrimps (526.44 kg/ha) obtained during the season 1978-79 from the traditionally operated field (Table 2) is highly attractive.

50,000-2,00,000/ha (Mammen, 1978; Rao, 1980; Sebastian *et al.*, 1980) seem to be reasonable. However Siddharaju *et al.* (1980) have reported still higher stocking densities (40-70/m^2) in which a production of 390 g/m^2 was obtained at Kovalam in cage culture of 120 days duration.

TABLE 3. *Statement showing the income and expenditure estimated from the results of the experimental monoculture of* P. indicus (Rs./ha)

Item	Amount (Rs.)	Item	Amount (Rs.)
INCOME		EXPENDITURE	
Sale proceeds of shrimp		Lease amount and licence fee ..	5,000.00
At 80% harvesting efficiency and @ Rs. 20/kg		Sluice gate ..	1,000.00
(Value of the 1166.72 kg of prawns available during Jan.-April) ..	23,334.40	Preparation of field ..	1,000.00
Value of the 50% of the above expected from the crop during Oct.-Jan. ..	11,667.20	Cost of stocking material and transportation (2,00,000/ha) ..	4,000.00
		Auxiliary feeding ..	1,000.00
		Wages for workmen ..	3,600.00
Total income ..	35,001.60	Interest on capital investment @ 15% ..	562.50
		Harvesting expenditure @ Rs. 3/kg ..	5,253.00
		Handling and marketing charges ..	1,000.00
		Contingent expenditure ..	500.00
Profit ..	12,086.10	Total expenditure ..	22,915.00

In India very little information is available on the monoculture of *P. indicus*, as attempts in this line began only in recent years. Some estimates on the stocking density and yield of this species reported from various brackish water systems in India are presented for comparison (Table 4). As can be read from the table relatively higher yield of *P. indicus* (704.4 kg/ha) was obtained in 70 days of culture under a stocking density of 37,000/ha (Sundararajan *et al.*, 1980). About twice this quantity obtained in the present case can mainly be attributed to the high stocking density applied. In this perspective the recent estimates of seed requirement for the intensive cultivation of *P. indicus* in Kerala waters ranging from

The rates of growth and survival of *P. indicus* vary considerably not only in relation to stocking density but to the environmental characteristics prevailing in different water systems. In the monoculture enclaves as well as in the open field at Narakkal a gradual increase in environmental parameters (Table 1) could be seen from January to April, a common feature of the backwaters during the season. The gradual degradation of the paddy stumps might be enriching the field with organic matter and at the same time leaching of nutrients into the overlying water enhances the photosynthetic activity which is reflected in the diurnal variation in the oxygen level. These factors seem to accelerate the growth of shrimps in paddy

TABLE 4. *Comparative statement of stocking and harvesting in the monoculture of* P. indicus *in various brackish water regions in India*

	Place/Reference							
	Santhome Fish Farm, Madras (Sundararajan *et al.*, 1980)		Brackish water Exp. Fish Farm, Kakdwip		Brackish water Farm, Kakinada	Present data		
Stocking density (No./ha) of *P. indicus* ..	70,000	37,000	50,000	25,000	70,000	2,00,000	2,00,000	2,00,000
Size at stocking (mm) ..	42.2	48.5	24.0	20.0	45.00	36.00	36.00	36.00
Size at harvest (mm) ..	130.7	147.5	97.3	100.00	120.0	83.34	91.93	115.94
Culture days ..	130	70	90	70	180	28	56	84
Rate of survival (%) ..	32.2	91.5	57.2	55	—	85.2	81.8	65.0
Average growth/day (mm) ..	0.68	1.41	0.81	1.14	—	1.72	1.01	0.96
Estimated total production kg/ha. ..	301.8	704.4	475.0	310.0	243.14	640.0	874.0	1458.0

fields during this period. The accumulation of photosynthetic material, unconsumed food, dead animals and metabolic wastes might have resulted in the higher value of organic carbon (4.14%) within the enclave at the end of the experiment. The formation of the floating patches of scum is the outcome of these decomposing organic material. This has produced a state of pollution which can be understood from the drastic fall of oxygen level (1 ml/l) particularly at night. The relatively low survival noticed among the larger individuals as shown in the histogram clearly indicates the adverse effect of the deteriorating medium though the oxygen minimum was well above the suffocation level for penaeid shrimps as proved by Shigueno (1975). However surfacing of larger shrimps during the early hours of the day observed in the enclave especially after the 10th week suggests their intolerance to the decreased oxygen content as observed by Subramaniam (1962) in the same species. This indicates the inability of the medium to support dense cultures like this for longer period.

It could be seen from the data (Table 2) that the shrimp yield from the traditionally operated field (526.44 kg/ha) continued to show a downward trend in recent years as has been pointed out by Gopalan *et al.* (1980). At the same time total production including fishes (1492.44 kg/ha) showed a marginal increase which is mainly due to the dominance of *Tilapia* which has been treated as a pest in brackish waters of Indonesia, Ceylon and Thailand (Pillai, 1972). The yields of 640.0, 874.0 and 1458.0 kg/ha obtained respectively after 4, 8 and 12 weeks of monoculture of *P. indicus* suggest the lines for future planning and development of paddy field shrimp culture.

On the whole the results of the present experiment reveal potentiality of paddy field ecosystem of Kerala to sustain a many fold increase in the production of quality shrimps. If carefully managed, two short-term, high density crops of *P. indicus* are possible during the non-paddy season. Nevertheless the present data has its limitations as it is projected from the operation of relatively smaller area (25 m^2) which facilitated the harvesting of all the surviving shrimps. In larger systems percentage recovery may not exceed 80% of the surviving shrimps. With this allowance it can be estimated that a total of 1750.08 kg/ha of shrimps valued at Rs. 35,001.60 could be harvested in two crops.

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PRAWN SEED RESOURCES OF THE ESTUARIES IN THE MANGALORE AREA

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ABSTRACT

A survey of the juvenile prawn resources of three estuaries *viz.*, at Kasaragod, Mangalore and Mulki along the Karnataka coast was undertaken during 1969-72 by operating a drag net. The magnitude of the resource and its composition (species and size-wise) and the seasons of availability are dealt with in this account. The environmental parameters such as temperature and salinity are also presented.

INTRODUCTION

PRAWNS constitute about one seventh of the total marine fish production of India (CMFRI, 1979). Nearly two thirds of the prawn production is by the penaeid group which is of great export value. However, the exploitation of a natural resource has got its own limitations. Hence, there has been a global awakening to find out ways and means of augmenting fish production through coastal aquaculture.

It is well known that penaeid prawns spend their early life in the estuaries and near shore waters. The estuarine phase in their life history affords ample scope for collection of fry and stocking them for culture purpose. Though the Karnataka Coast has about 5000 ha. of estuarine areas, no information is available regarding the occurrence of prawn fry except for an account on the capture fisheries of the Mangalore Estuary (Ramamurthy, 1972). A knowledge of the availability of prawn fry and its composition in space and time is essential for planning aquaculture on scientific basis. The present paper deals with these aspects from three estuarine systems during 1969-72. Besides, the environmental parameters *viz.*, temperature and salinity have also been considered.

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MATERIAL AND METHODS

The material for this study came from 3 estuaries namely, the Chandragiri Estuary at Kasaragod in the south and the Shambhavi Estuary at Mulki in the north with Gurpur Estuary at Mangalore in between these two centres. Though Kasaragod is in Kerala, in view of its close proximity, it is considered along with other centres of the Karnataka Coast. While the study centre at Mangalore lies within a distance of 1 km from the bar, the other centres are about 1½ km from the bar.

A drag net consisting of 5 pieces (5.0 × 2.7 m each) with a stretched mesh varying from 0.9 to 2.5 cm was operated at ebb tide between 0630 and 0830 hrs. in depths of 0.5-2.5 m. The net was cast in a semicircular pattern from a boat and then dragged at either ends towards the shore. The number of hauls on a day varied from 3 to 5. Normally the frequency of fishing was twice a month and was carried out during the 3rd and 5th day following the full/new moon. During January-March 1969,

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fishing was also conducted in the evening to get a comparative picture of the yield at different times of the day. During the monsoon (June-August) fishing operations became often impossible due to the swollen nature of the rivers.

The weight of the prawn and fish catch was separately recorded. Random samples of the prawn catch were sorted out species-wise and their weight and total length (from the tip of rostrum to the tip of telson) were recorded. The *CPUE* is expressed in terms of a haul. Since each haul is estimated to cover an area of about 50 sq.m the *CPUE* is also regarded as density per 50 sq.m. Salinity was estimated by the Mohr's method of titration of chlorides.

Hydrological Conditions

All the estuaries have connection with the sea throughout the year. The bottom is muddy, mixed with sand. The tidal difference varied from 0.15 to 1.80 m depending upon the phase of the moon.

The surface temperature and salinity values on the observed days at the three centres during the different years are plotted in Fig. 1.

Kasaragod : The temperature varied from 24.5°C during July 1971 to 32.5°C during April 1969. Generally, it remained high during March-April (30.0-32.5°C) and low during June-August (24.5-28.0°C) coinciding with the monsoon. A secondary rise in temperature was noticed during October-November (29.0-31.0°C). However, during 1971 and 1972 this occurred in August (29.2°C) and December (32.1°C) respectively.

Salinity ranged from 0.37‰ during August, 1970 to 34.90‰ during April, 1972. The values were high during Jan-April (27.93-34.90‰) with peak during March-April. During 1969, however the peak was observed in May. With the onset of monsoon the values gradually declined and touched lowest values during July-August (0.37-2.20‰). Subsequently the salinity steadily registered a increase to reach the peak in the summer months.

Mangalore : The range in temperature and salinity values was respectively from 25.9°C in July, 1972 to 31.8°C in April, 1969 and from 0.37‰ in August, 1970 and July, 1972 to 34.72‰ in April, 1969. The seasonal variations were generally similar to these at Kasaragod. However the peak values in temperature (30.8-31.0°C) were recorded during May of 1971 and 1972.

Mulki : The minimum and maximum values for temperature and salinity were respectively 25.2°C in August, 1970 and 32.5°C in April, 1969 and 0.24‰ in August, 1971 and 36.47‰ in May, 1972. The seasonal trends were similar to those at the other two centres.

Juvenile Prawn Resource

The annual average catch of fish and prawns and the constituent species with their percentage composition is shown in Table 1. Figs. 1-4 depict the catch of prawns and the various species with size range and mean length on the observed days.

The prawn catch showed wide variations. It surpassed the fish catch quite often during October-December and occasionally during August-September, February and April. 90-95% of prawns belonged to the penaeid group comprising of mostly *Metapenaeus dobsoni*, *Penaeus indicus*, *M. monoceros* and *P. merguiensis*. Species of lesser importance were *P. monodon* and *P. semisulcatus*. *M. affinis*, *M. burkenroadi* and *Parapenaeopsis stylifera* were rarely caught. The non-penaeids were represented by *Macrobrachium idae* and *M. rude*. Crabs (*Scylla serrata*) were occasionally caught in appreciable numbers.

TABLE 1. *Annual prawn catch composition at different centres* (CPUE in g ; numbers in parenthesis)

Year	*M. dobsoni*	*M. monoceros*	*M. affinis*	*P. indicus*	*P. merguiensis*	*P. monodon*	*P. semisulcatus*	*M. burkenroadi*	Non-Penaids	Total prawns	Fish	Prawns percentage
					Centre : KASARAGOD							
1969	90.7(123)	6.1(5)	—	29.4(13)	1.6(1)	3.0	—	—	1.0	131.8	182.5	42.2
(% Wt)	68.8	4.6		22.3	1.2	2.3			0.8			
1970	17.6(58)	14.3(17)	0.4	24.2(22)	—	0.2	—	—	5.5	62.2	126.6	32.9
	28.3	23.0	0.6	38.9		0.3			8.9			
1971	100.2(394)	12.8(23)	—	21.2(88)	—	3.2	—	—	1.5	138.9	157.8	46.8
	72.1	9.2		15.3		2.3			1.1			
1972	57.7(59)	30.6(29)	—	9.7(30)	—	1.3	0.8	—	11.0	111.1	189.0	37.0
	51.9	27.5		8.7		1.2	0.7		10.0			
Average	66.5(159)	16.0(19)	0.1	21.1(38)	0.4	1.9	0.2	—	4.8	111.0	164.0	40.0
(% Wt)	59.9	14.4	0.1	19.0	0.4	1.7	0.2		4.3			

Centre : MANGALORE

1969	11.1(16)	1.6(1)	0.2	12.4(3)	12.6(3)	1.1	—	—	1.8	40.8	1460.7	2.7
	27.2	3.9	0.5	30.4	30.9	2.7			4.4			
1970	26.2(48)	3.7(2)	—	14.4(8)	1.3	2.1(1)	—	—	1.0	48.7	234.9	17.2
	53.8	7.6		29.6	2.7	4.3			2.0			
1971	65.2(287)	4.6(5)	0.1	17.4(8)	—	0.2	—	—	2.6	90.1	124.1	42.1
	72.4	5.1	0.1	19.3		0.2			2.9			
1972	60.0(198)	8.6(7)	0.2	22.9(12)	2.5(1)	5.1	1.5	—	8.0	108.8	136.5	44.3
	55.1	7.9	0.2	21.0	2.3	4.7	1.4		7.4			
Average	40.6(137)	4.6(4)	0.1	16.8(8)	4.1(1)	2.1	0.4	—	3.4	72.1	489.0	12.8
	56.3	6.4	0.1	23.3	5.7	2.9	0.6		4.7			

Centre : MULKI

1969	22.7(91)	3.5(2)	0.4(2)	21.7(13)	7.8(4)	0.3	—	0.1	1.4	57.9	258.3	18.3
	39.2	6.0	0.7	37.5	13.5	0.5		0.2	2.4			
1970	8.2(47)	1.2(2)	0.1	5.8(16)	0.9(1)	0.1	—	—	0.3	16.6	118.7	12.3
	49.4	7.2	0.6	35.0	5.4	0.6			1.8			
1971	45.3(136)	8.7(12)	—	13.7(48)	—	2.1	—	—	1.0	70.8	136.2	34.2
	64.0	12.3		19.3		3.0			1.4			
1972	8.8(61)	1.5(5)	—	18.8(47)	0.3	2.5	1.0	—	1.3	34.2	149.9	18.6
	25.7	4.4		55.0	0.9	7.3	2.9	—	3.8			
Average	21.3(84)	3.7(5)	0.1	15.0(31)	2.3(1)	1.3	0.2	—	1.0	44.9	165.8	21.3
	47.4	8.3	0.2	33.4	5.1	2.9	0.5		2.2			

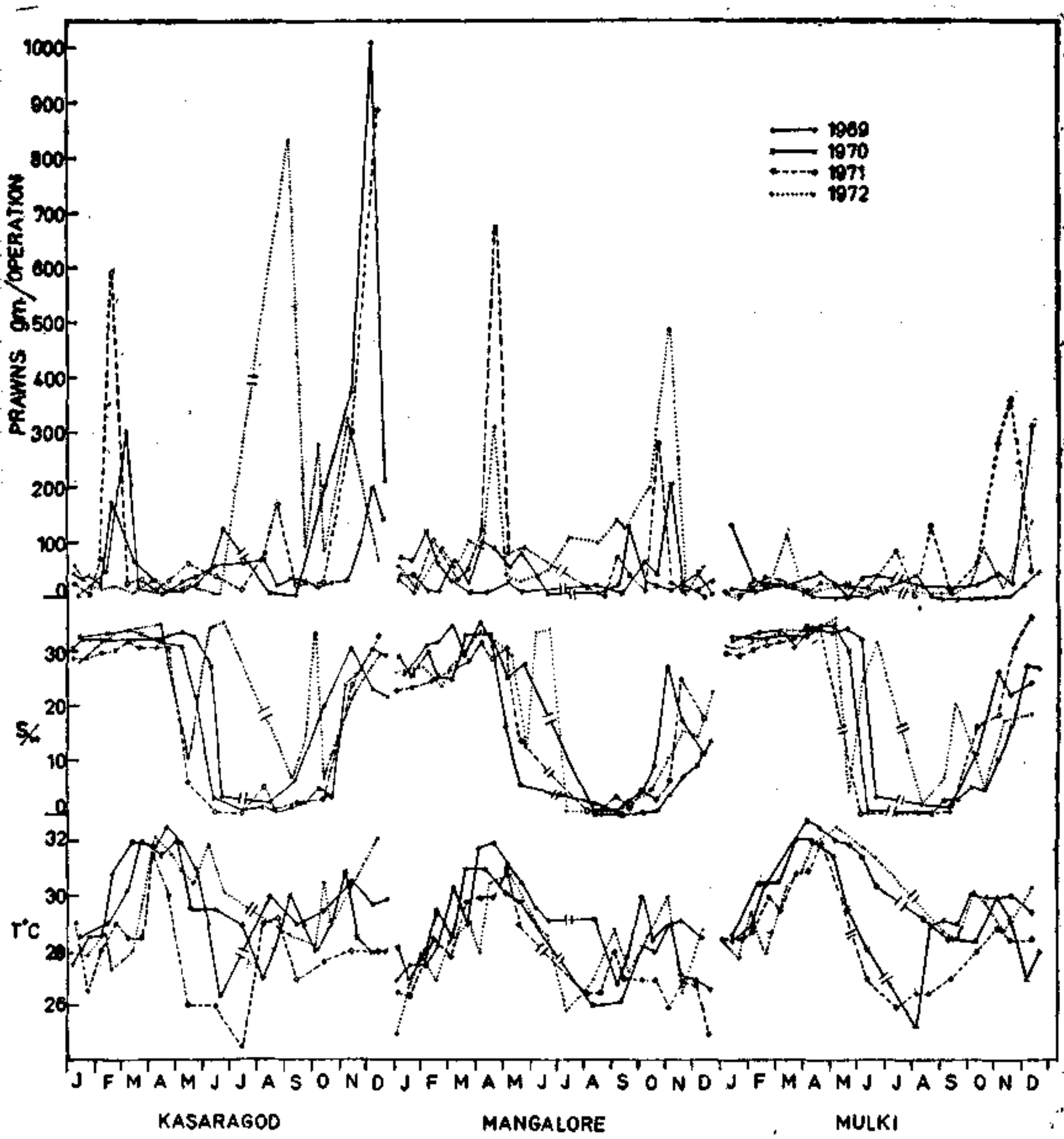

Fig. 1. Seasonal variations in surface temperature, salinity and juvenile prawn catch at different centres during 1969-72.

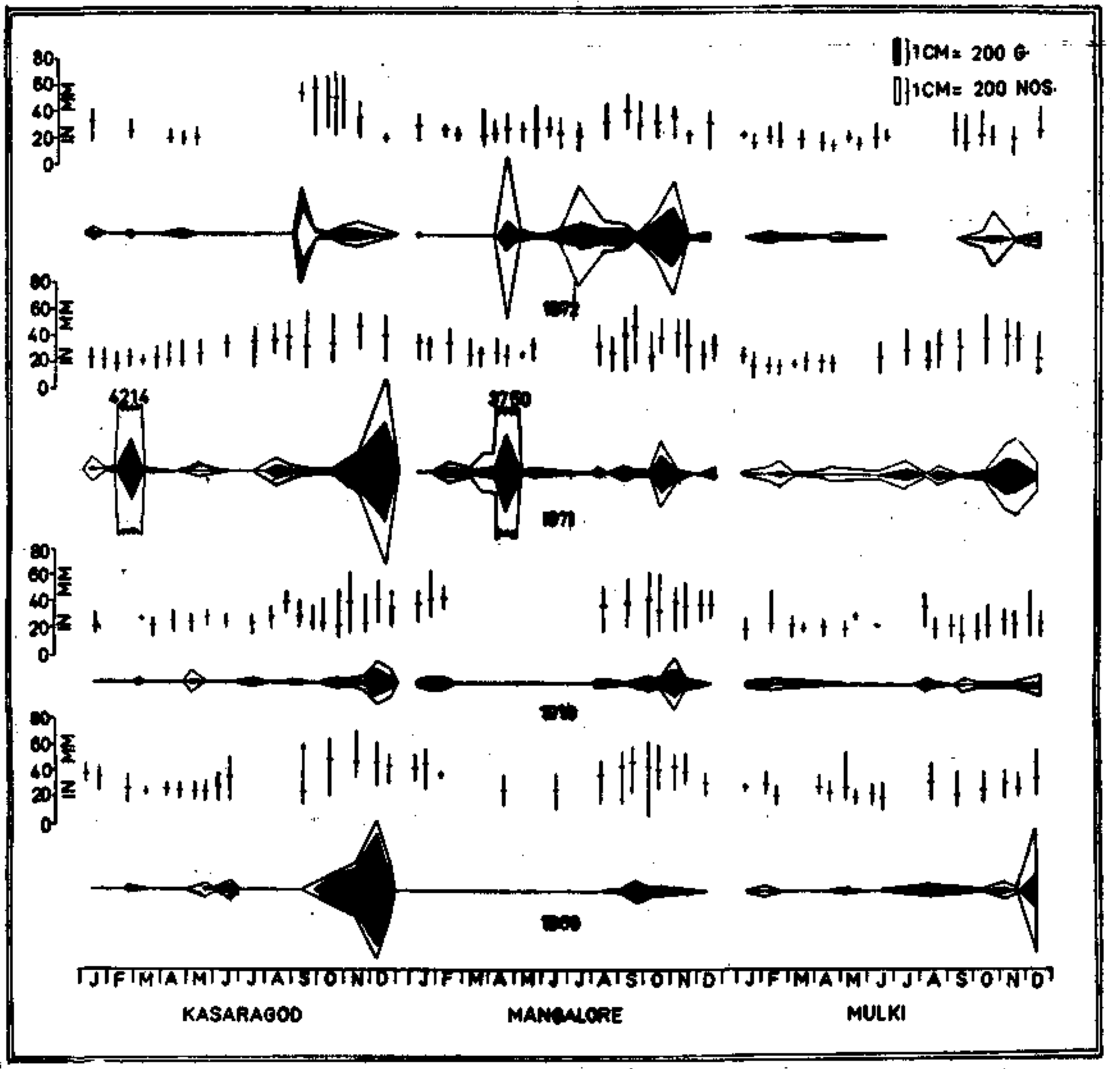

Fig. 2. Seasonal abundance of juvenile *M. dobsoni* in CPUE and size composition at different centres during 1969-72.

The fish catch consisted mostly of species of *Ambassis*, *Mugil*, *Stolephorus*, *Thrissocles*, *Tachysurus*, *Lates*, *Therapon*, *Sillago*, *Gerres*, *Etroplus*, *Tilapia* and *Platycephalus*.

Polyzoans and sea-weeds appeared in considerable quantities during January-March of 1971 and 1972 at Mulki.

The salient features of observation at the different centres are summarised below:

Kasaragod: Prawns constituted 32.9 to 46.8% of the total catch during the different years. The catch was generally poor during the monsoon months when the estuarine areas were freshened due to influx of rain water.

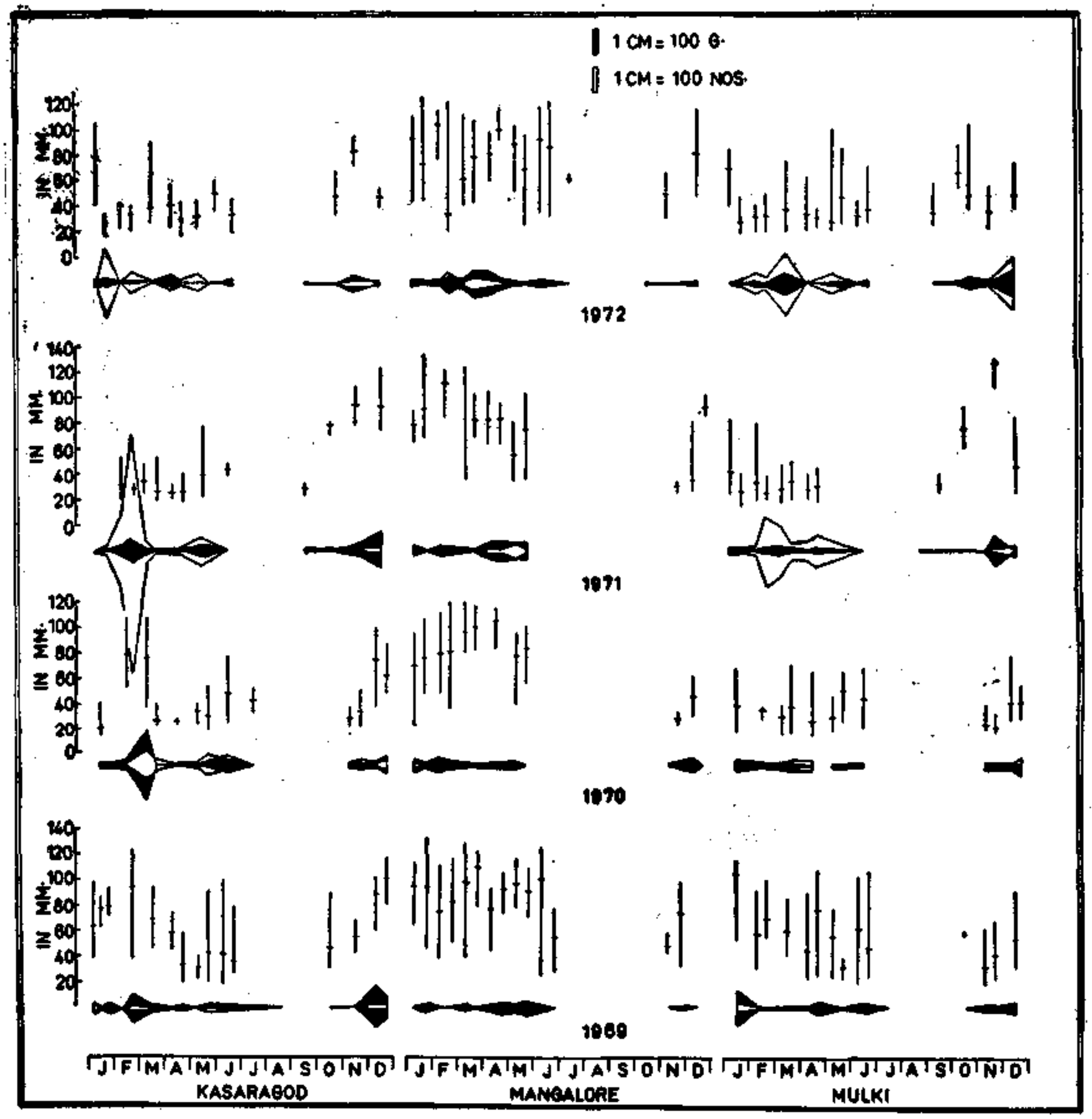

Fig. 3. Seasonal abundance of juvenile *P. indicus* in CPUE and size composition at different centres during 1969-72.

The peak period of prawn catch was generally in the post-monsoon period and was noticed in December, March, December and September respectively during the four years of study. The chief species was *M. dobsoni* followed by *P. indicus* and *M. monoceros*. However, during 1970, *P. indicus* was the predominant species.

M. dobsoni was more common during 1969 and 1971. The period of abundance was September-December. During 1971, it was abundant in February also. *P. indicus* was better represented during 1970 and 1971. The species was common during January-March and November-December. *M. monoceros* was rare in 1969. But it was of common occur-

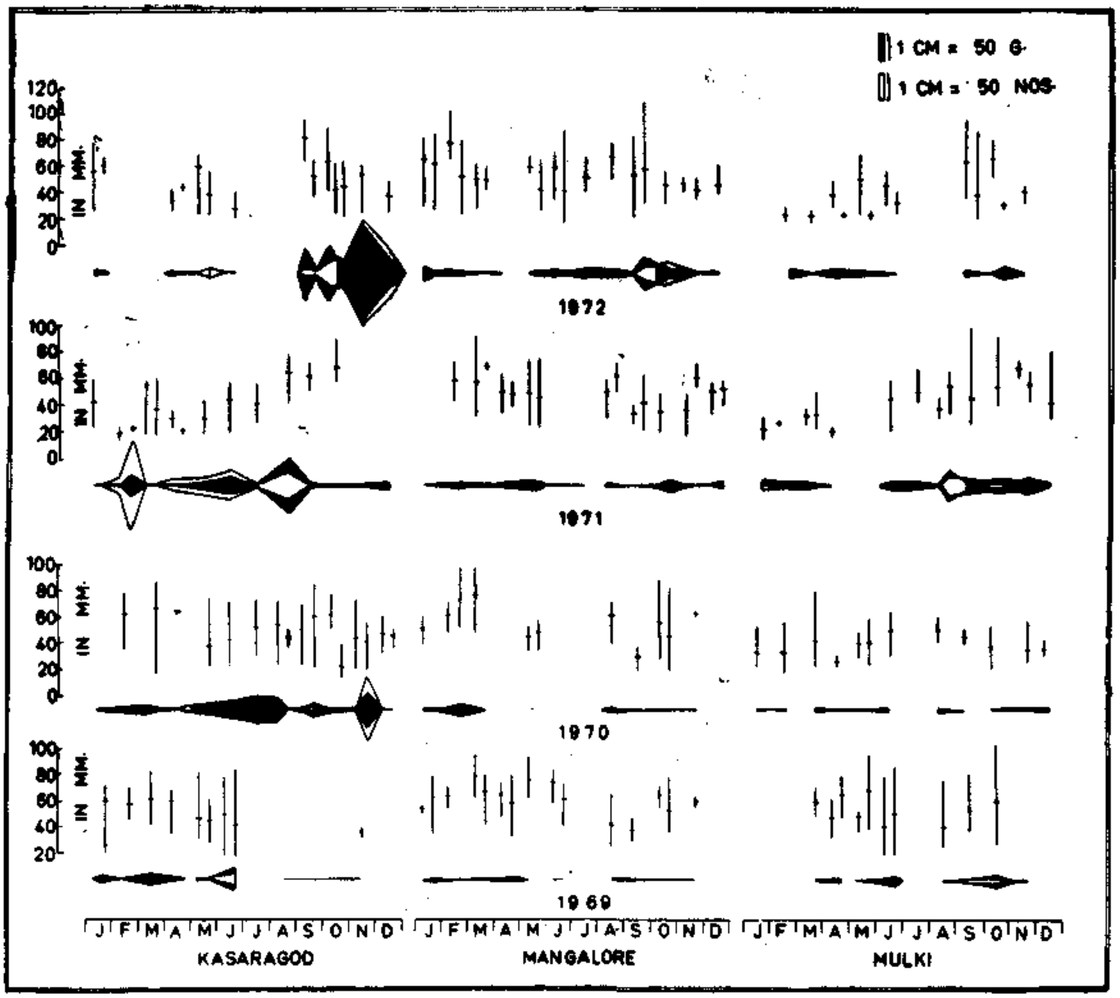

Fig. 4. Seasonal abundance of juvenile *M. monoceros* in CPUE and size composition at different centres during 1969-72.

rence during June, August and November in 1970, February-August in 1971 and September-November in 1972.

Mangalore: The prawn component varied from 2.7 to 44.3% of the total catch. The peak occurred during September, November, April and November during the four years respectively. The species composition was similar to that at Kasaragod. *P. indicus*, however, was the major species during 1969. Another notable feature was the occurrence of *P. merguiensis* in appreciable quantities during this year.

M. dobsoni was poorly caught during 1969 and 1970. The peak occurrence was during September-November. During 1971 and 1972, this species was very common in April also. *P. indicus* was more common during 1971 and 1972. The peak was during March-May. *M. monoceros* was poorly represented except in 1972, when the peak was during September-October.

Mulki: The percentage composition of prawns in the total catch varied from 12.3 to 34.2. The maximum catch of prawns was noticed in December except during 1971 when it was in November. The catch composition was similar as before. However, during 1972, *P. indicus* outweighed *M. dobsoni*. *P. merguiensis* was also well represented during 1969.

M. dobsoni was common in 1969 and 1971. The peak occurred during October-December. *P. indicus* had better representation during 1971 and 1972. The period of abundance was February-March and November-December. *M. monoceros* was caught in fair magnitude only during 1971, the peak period being August-October.

The resources characteristics of the three major species at the various centres are given in Table 2.

Among the species of lesser importance, *M. affinis* and *P. monodon* were caught more frequently at Mangalore during January-May than at the other centres. The former ranged from 16 to 76 mm with mean length 25-45 mm being predominant. The latter measured 31-178 mm with mean length 45-80 mm being common. *P. semisulcatus* and *M. burkenroadi* were rare and occurred during February-June in the size range of 25-104 mm and 17-81 mm respectively.

Diurnal Variations in Catch

The prawn catch was observed to be better in the evening than in the morning during January-February and vice versa during March (Tables 3, 4). The ebb tides were also lower in the evening than in the morning during the two months and vice versa in March. Thus it is evident that the prawn catch was better when the tidal difference was greater. There were, however, no significant differences in the catch and size composition of the species.

General Remarks

One striking feature that has emerged from the present study is that the resource of juvenile penaeids in the various estuaries decreases from south to north along the coast. Thus the Kasaragod Estuary supports the most abundant resource and the Mulki Estuary the least abundant. The composition of the population has been, however, observed to be more or less identical at all the centres and akin to that of the Cochin Backwaters observed by Kuttyamma and Antony (1975).

Of the three major species viz., *M. dobsoni*, *P. indicus* and *M. monoceros* which occurred in the order of abundance, all except the second one were caught almost throughout the year, though variations were noticed in their abundance. *M. dobsoni* had the peak generally during September-December and occasionally during February-April and July. It is esti-

TABLE 2. *Resource characteristics of penaeid species at various centres*

Centre	Species	Range in maximum CPUE values		Size range in mm (Jan.-June)		Size range in mm (July-Dec.)	
		In Grams	In numbers	Total length	Common mean length	Total length	Common mean length
Kasaragod	*M. dobsoni*	180-841 (Dec. '70) (Dec. '69)	321-4214 (Dec. '70) (Feb. '71)	14-44	20-30	14-72	40-50
	P. indicus	64-286 (Nov. '72) (Mar. '70)	37-925 (Dec. '69) (Feb. '71)	14-124	20-40	21-124	80-95
	M. monoceros	40-129 (June '69) (Nov. '72)	38-200 (June ' 69) (Nov. '72)	14-84	20-50	13-96	40-65
Mangalore	*M. dobsoni*	119-600 (Sept. '69) (Apr. '71)	148-3750 (Sept. '69) (Apr. '71)	12-661	20-30	8-68	35-50
	P. indicus	52-92 (May '69) (Mar. '72)	12-81 (May '69) (Feb. '72)	20-134	70-90	20-118	20-50
	M. monoceros	12-56 (May '71) (Sept. '72)	8-42 (Feb. '70) (Oct. '72)	17-102	60-80	18-108	40-60
Mulki	*M. dobsoni*	30-267 (Dec. '70) (Dec. '69)	163-942 (Dec. '70) (Dec.' 69)	8-57	20-30	12-62	25-45
	P. indicus	16-130 (Jan. '70) (Jan. '69)	28-266 (Jan. '69) (Feb. '71)	14-116	25-40	18-130	35-50
	M. monoceros	23-52 (Oct. '69) (Aug. '71)	10-40 (Oct. '69) (Aug. '71)	14-98	20-40	20-104	40-60

TABLE 3. *Catch details of morning haul at Mangalore* (CPUE in g and numbers in parenthesis)

Date	Lowest tide (m)	Fish	Prawns	Species of prawns						
				M. dobsoni	*M. monoceros*	*M. affinis*	*P. indicus*	*P. merguiensis*	*P. monodon*	Others
7.1.69 ..	0.86	173.0	39.0	0.9(2)	0.5	—	8.0(1)	29.4(6)	—	0.2
Size range (mm) ..				34-54	51-57	—	64-113	54-104	—	—
Mean length („) ..				43.2	54.3	—	95.0	86.0	—	—
21.1.69 ..	0.59	52.0	42.0	3.0(5)	2.0(2)	—	34.0(7)	—	1.0(1)	2.0
Size range (mm) ..				27-58	34-80	—	47-133	—	—	—
Mean length („) ..				47.0	63.0	—	94.0	—	52.0	—
4.2.69 ..	0.76	202.0	10.0	0.3(1)	0.5	2.3(3)	1.8	4.4(1)	0.6	0.1
Size range (mm) ..				36-40	54-72	27-72	38-112	68-113	41-79	—
Mean length („) ..				38.0	63.0	44.0	75.0	80.0	70.0	—
17.2.69 ..	0.64	109.0	10.0	—	0.6	0.2	3.0	6.2(1)	—	—
Size range (mm) ..				—	—	35-60	51-117	74-121	—	—
Mean length („) ..				—	—	—	83.0	100.0	—	—
6.3.69 ..	0.47	219.0	66.0	—	2.1	0.4	20.4(4)	38.0(10)	2.4	2.7
Size range (mm) ..				—	63-95	28-54	38-125	72-115	75-95	—
Mean length („) ..				—	79.0	40.0	98.5	88.7	80.0	—
20.3.69 ..	0.27	515.0	27.0	—	2.5(1)	0.3	8.5(1)	13.5(3)	2.2	—
Size range (mm) ..				—	41-80	—	78-128	70-105	—	—
Mean length („) ..				—	65.8	—	110.0	87.8	—	—

TABLE 4. *Catch details of evening haul* (CPUE in g and numbers in parenthesis)

Date	Lowest tide (m)	Fish	Prawns	Species of prawns						
				M. dobsoni	*M. monoceros*	*M. affinis*	*P. indicus*	*P. merguiensis*	*P. monodon*	Others
7.1.69	0.35	215.0	82.0	20.0(35)	12.0(10)	2.0(2)	12.0(3)	36.0(11)	—	—
Size range (mm)				37-51	37-81	40-50	84-108	52-98	—	—
Mean length („)				42.0	55.0	46.0	95.0	80.0	—	—
21.1.69	0·29	712.0	150.0	74.0(72)	7.0(4)	8.0(22)	15·0(5)	—	46.0(40)	—
Size range (mm)				42-61	57-80	24-53	34-122	—	21-74	—
Mean length („)				52.0	66.0	37.0	70.0	—	43.0	—
4.2.69	0.33	137.0	27.5	0.2(1)	—	13.7(15)	4.2(1)	8.3(2)	0.3	0.8
Size range (mm)				33-40	—	25-92	100-112	73-84	29-65	—
Mean length („)				37.0	—	48.0	107.0	79.0	47.0	—
17.2.69	0.24	120.0	155.0	18.0(112)	6.3(3)	42.5(64)	49.0(5)	22.5(4)	11.7(2)	5.0
Size range (mm)				19-39	61-104	21-71	99-136	82-104	74-91	—
Mean length („)				28.0	74.0	46.0	118.0	94.0	80.0	—
6.3.69	0.55	218.0	56.0	0.1	0.7	0.7	22.0	15.8	16.7	—
Size range (mm)				20-24	37-61	28-60	67-121	68-104	31-170	—
Mean length („)				22.0	47.5	46.0	99.1	81.1	105.0	—
20.3.69	0.62	246.0	23·0	—	4·3	0.5	8.1	5.9	0.7	3.5
Size range (mm)				—	47-93	55-62	50-108	68-103	48-70	—
Mean length („)				—	71.4	58.5	93.4	89.4	59.0	—

mated from the present study that over eight lakh seeds/ha could be collected during the peak season at Kasaragod. *P. indicus* was of common occurrence during February-May and November-December. It was virtually absent during the monsoon when the salinity of the estuarine areas was reduced almost to fresh water condition due to influx of rain water. Nearly two lakh seeds/ha is the estimated potential at Kasaragod. Mulki appears to be the next best centre for seed collection of this species with a potential of over half a lakh seeds/ha. *M. monoceros* was the least abundant and occurred relatively more during August-October with a potential of 0.4 lakh seeds/ha at Kasaragod.

Despite the preponderance of *M. dobsoni* in the catches, this species is uneconomic for culture purpose since it grows to only 13 cm in the sea, the maximum size recorded in the backwaters being 9 cm (Menon and Raman, 1961). On the other hand, *P. indicus* attains a size of 14 cm in the backwaters and grows to a maximum size of 23 cm in the sea. In view of its comparatively faster rate of growth (George, 1975), *P. indicus* holds immense scope for aquaculture. Taking into consideration the stockable size, the best period for collection of fry is January-March (particularly on days when the tidal difference is greater) when juveniles of 2-4 cm long are available.

The Mangalore Estuary has a relatively better representation of *P. monodon*, the 'jumbo tiger prawn' which grows to 32 cm in the sea. In the backwaters, sizes upto 15 cm are known to occur (Subrahmanyam and Ganapati, 1975). Perhaps a more efficient method of collection as practised in Philippines (Bardach *et al.*, 1972) can be adopted to augment the seed requirements for culture of this species.

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PRAWN SEED CALENDARS OF COCHIN BACKWATER

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ABSTRACT

The paper presents a consolidated monthly picture of the availability of penaeid prawn seeds in Cochin backwater (between Thoppumpady and Mulavukad) based on the results of routine monitoring studies carried out from 1967 to 1979, using plankton net, try net (miniature trawl) and velon screen drag net. The prawn seed population, comprising postlarval and early juvenile stages, is represented by thirteen species, of which, *Metapenaeus dobsoni*, *M. affinis*, *M. monoceros*, *Penaeus indicus* and *P. semisulcatus* are the most common. While *M. dobsoni* forms the chief constituent in the plankton collections (88%) and try net catches (46%), *P. indicus* predominates in the velon screen drag nets (93%) operated in shallow areas close to the shore. *M. affinis* occurs in greater abundance in the deeper areas as evidenced by its high percentage (45%) in the try net catches.

The environmental conditions of the backwater and the relative abundance and size distribution of the seeds of different species as represented in the three methods of collections are summarised month-wise. Although prawn seeds are available throughout the year, the peak seasons of important species are August-January for *M. dobsoni*, May-July for *M. affinis*, December-April for *M. monoceros*, March-May for *P. indicus* and January-March for *P. semisulcatus*.

INTRODUCTION

AVAILABILITY of adequate quantity of the seeds of desired species at the appropriate time is one of the important factors that determine the success of prawn culture. Estuaries and backwaters are the important sources of prawn seed in nature as most of the cultivable species of prawns spend their juvenile phase in these environments. The Cochin backwater system in Kerala is the largest nursery ground for penaeid prawns in the west coast, where large scale prawn culture is carried out traditionally as well as on modern scientific lines. The fast expansion of culture fisheries now taking place in this region entails greater demand for the seed and the necessity for increased search for them in this ecosystem. For a judicious exploitation of this resource it is essential to have precise information on the distribution and abundance of different species in space and time. The studies so far conducted from this area are mostly of a general nature on the recruitment and biology of some species, with little emphasis on their seed resources (Menon and Raman, 1961 ; George, 1962a, 1962b, 1963 ; Shetty, 1965 ; Mohamed and Rao, 1971 ; Rao and Kathirvel, 1971; Kuttyamma, 1975 ; Kuttyamma and Antony, 1975). Therefore, an attempt is made here to draw up seed calendars for this backwater based on the results of routine monitoring studies carried out from 1967 to 1979, with particular reference to penaeid prawns.

The material for this study was collected by weekly operation of three types of nets namely a half-metre plankton net (1967-'71), a velon screen drag net (1977-'79) and a try net (1969-'77) at different stations in the backwater between

Thoppumpady and Mulavukad (Fig. 1). The sampling with these different types of nets was attempted in order to cover all the areas occupied by the diffirent developmental stages of the prawns from postlarvae to early juveniles. The plankton net was towed against the current for 10 minutes near the bar mouth in the early hours of the day. The velon screen drag net, measuring 2 m long and 1 m wide, was dragged parallel to the shore for 2 minutes in the shallow near shore areas at Ramanthuruth in the morning. The try net, a miniature trawl specially designed for collecting prawn samples from deeper areas of the backwater measuring 4 m in overall length (5.4 m head rope and 5.4 m foot rope, with mesh size of 8 mm throughout), was operated for 15 minutes each time during the high tide and low tide periods of the day alternatively at Thoppumpady and Mulavukad. Data on salinity and temperature of the surface water were also recorded. The samples of seeds were analysed qualitatively and quantitatively and length measurements recorded for those obtained in the drag net and try net. The size of the seed was measured from the tip of rostrum to the tip of the telson.

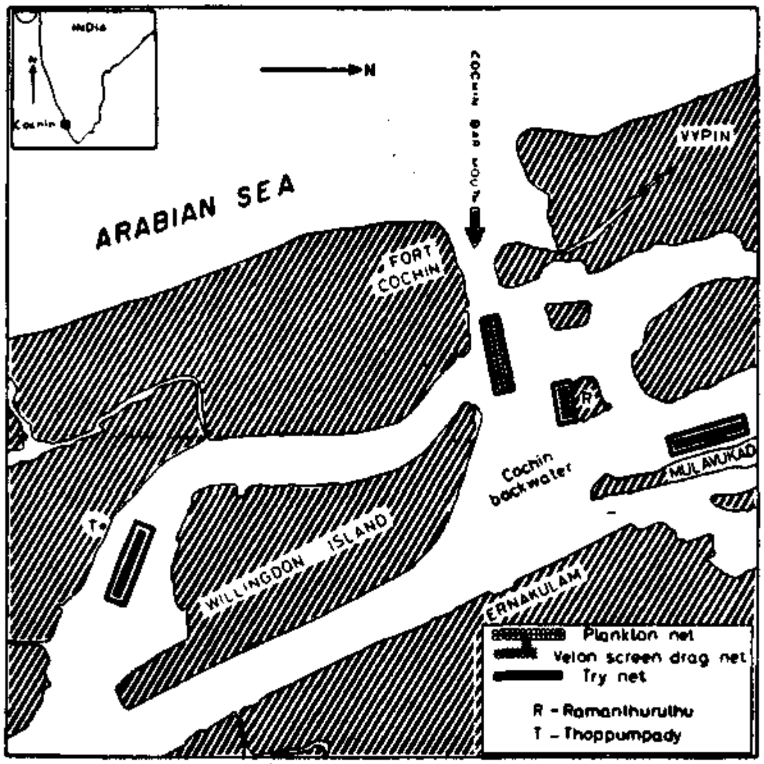

Fig. 1. Map showing the sampling stations.

The data thus collected were analysed in detail and monthly abundance of the seed of different species was worked out in terms of number/haul for each type of the net. The average number of seeds/haul of important species caught by the different types of nets have been tabulated month-wise and presented in Table 1.

TABLE 1. *Monthly abundance of prawn seeds in different types of nets*

Species	Net	Average number of seeds/haul											
		Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
P. indicus	PN	1	1	2	2	21	..	..	..	1	1	2	1
	VN	177	240	1,432	1,870	10,025	96	1	..	762	766	74	532
	TN	1	1	1	1	1	4	2	..	..	1	1	..
P. semisulcatus	PN	..	..	..	..	..	..	..	..	..	..	..	..
	VN	5	8	2	2	1	..	..	..	..	..	..	1
	TN	2	3	4	4	3	3	..	..	..	..	..	1
P. canaliculatus	PN	..	..	..	..	..	..	..	..	..	..	..	..
	VN	1	1	2	18	4	..	..	..	..	..	..	..
	TN	..	..	..	1	..	..	..	..	..	..	..	..
P. monodon	PN	..	..	..	..	..	..	..	..	..	..	1	..
	VN	..	..	..	..	1	..	..	..	1	..	..	..
	TN	..	..	3	3	..	..	..	..	..	..	..	..
M. dobsoni	PN	101	21	12	9	9	1	2	3	10	5	141	72
	VN	104	17	64	52	71	45	22	79	154	91	18	62
	TN	5	2	2	2	2	18	8	2	97	20	24	5
M. affinis	PN	2	1	..	2	1	1	..	..	..	..	1	1
	VN	..	..	..	2	3	..	..	..	..	..	..	..
	TN	7	6	6	8	16	44	85	4	2	1	2	3
M. monoceros	PN	1	1	1	..	..	..	..	..	..	1	5	1
	VN	15	15	26	34	2	5	1	1	..	3	..	25
	TN	..	..	1	1	1	5	10	1	1	1	..	..
P. stylifera	PN	..	..	..	..	..	..	..	..	..	..	..	..
	VN	..	..	..	..	..	..	..	..	..	..	..	..
	TN	3	2	3	3	..	..	..	..	..	..	2	8

During the field collections it was experienced that efficient seed procurement from this backwater depends to a great extent on favourable environmental conditions. Very often the operation of nets and sorting of seeds were rendered difficult on account of the interference of weeds (*Salvenia* and *Eichornia*) which have become a menace to this ecosystem in recent years. Similarly the physicochemical conditions such as flood, turbidity, movement of water, salinity, temperature etc. were also found to influence the occurrence of prawn seed. While preparing the calendars all these aspects have been considered and brief mention of the conditions prevailing in each of the months made along with details of seed abundance.

We are greatly indebted to Dr. E. G. Silas, Director, Central Marine Fisheries Research Institute for his keen interest and encouragement in this work. We are also thankful to Mr. K. H. Mohamed and Dr. P. Vedavyasa Rao for their constant guidance during the course of this study and to Dr. M. J. George for critically going through the manuscript and suggesting improvements.

Species of Prawns and Their General Composition

The seed collections made during this investigation included several species of prawns chiefly belonging to the families Penaeidae, Atyidae and Palaemonidae. Among the penaeid prawns a total number of 13 species were recorded and they are listed below:

Name of species		Net in which it was caught
Penaeus indicus H. Milne-Edwards	..	PN, VN, TN
P. monodon Fabricius	..	PN, VN, TN
P. semisulcatus de Haan	..	VN, TN
P. latisulcatus Kishinouye	..	TN
P. canaliculatus (Olivier)	..	VN, TN
P. penicillatus Alcock	..	TN
Metapenaeus monoceros (Fabricius)	..	PN, VN, TN
M. affinis (H. Milne-Edwards)	..	PN, VN, TN
M. dobsoni (Miers)	..	PN. VN, TN
M. burkenroadi Kubo	..	TN
Metapenaeopsis hilarula (de Man)	..	TN
Parapenaeopsis stylifera (H. Milne-Edwards)	..	TN
P. acclivirostris Alcock	..	TN

PN—Plankton net ; VN—Velon screen drag net ; TN—Try net.

While all these species were encountered in the deeper portion of the backwater only few of them occurred in the surface plankton and nearshore areas. Out of the thirteen species listed above five species namely *Penaeus indicus, P. semisulcatus, Metapenaeus dobsoni, M. affinis* and *M. monoceros* were the most common. The composition of these species showed considerable variation in the different types of nets. Fig. 2 shows the overall species composition. It can be seen that *M. dobsoni* forms the major component of the tow net and try net

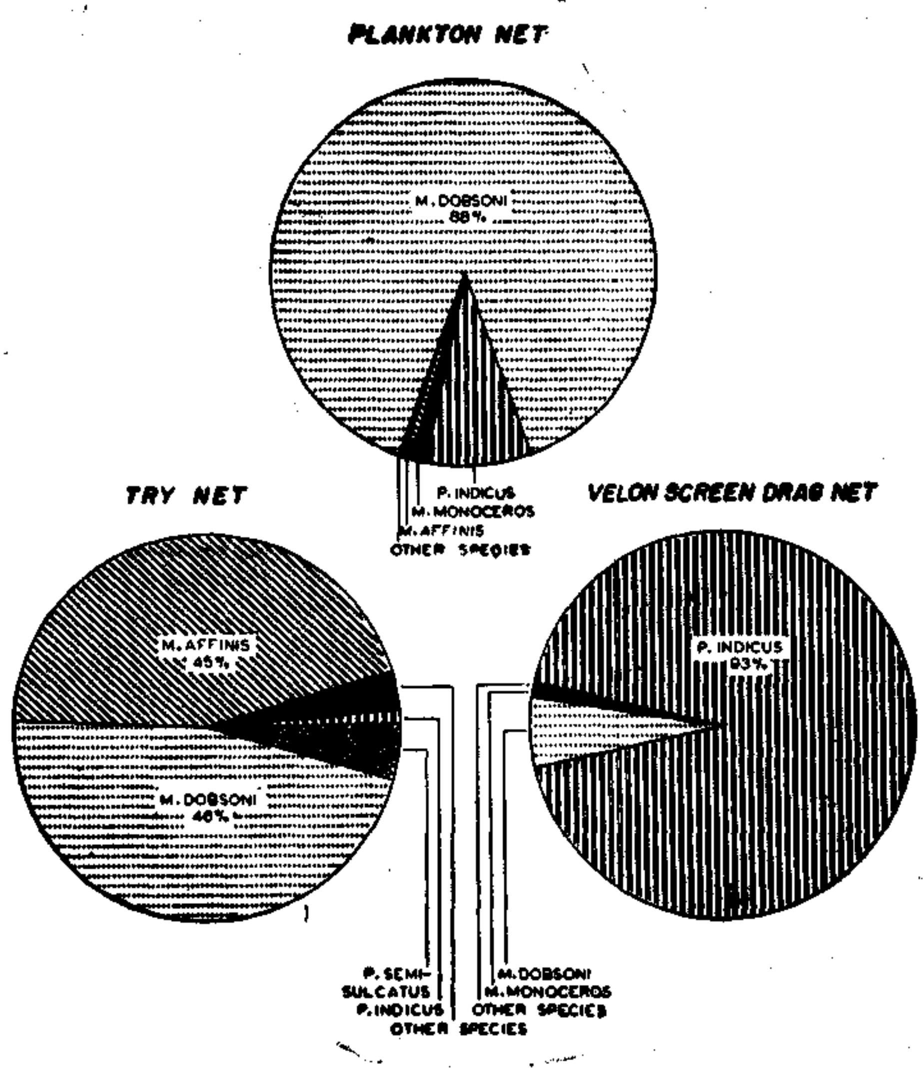

Fig. 2. Species composition of seeds in the different types of nets.

collections, contributing to 88% and 46% respectively. In the velon screen drag net, on the other hand, *P. indicus* is the predominant species forming as much as 93%. *M. affinis* and *P. semisulcatus* are only rarely encountered here, while they constitute a sizeable portion in the try net catches (45% and 4% respectively) from deeper areas.

Seed Size

The seed sizes considered here comprise postlarval stages and early juveniles upto 35 mm size in the case of species belonging to genus *Metapenaeus* and upto 50 mm size for others. In the plankton collections the seeds are predominantly represented by postlarval stages

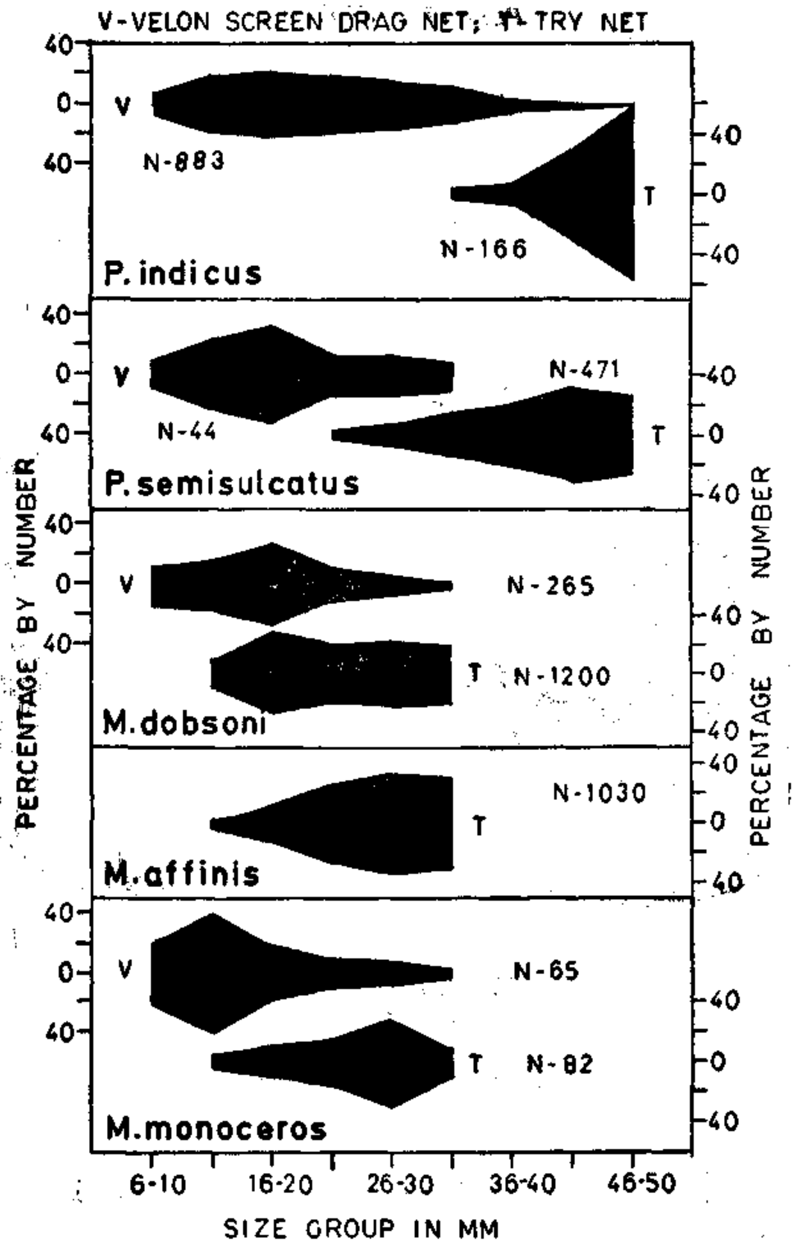

Fig. 3. Size distribution of important species.

I to IV. Sometimes late-mysis stages are also encountered in few numbers. The seeds collected from the shallow nearshore areas are generally smaller in size than those obtained from deeper grounds and include both advanced postlarvae as well as early juveniles. The postlarval stages mostly belong to species of the genus *Penaeus* measuring 8 mm to 17 mm in total length. The overall size distribution of the seeds of important species caught by velon screen drag net and try net are depicted separately in Fig. 3. It can be seen that the important sizes of seed collected by velon screen drag net is 11-35 mm for *P. indicus*, 11-20 mm for *P. semisulcatus* and *M. dobsoni* and 6-20 mm for *M. monoceros*. In the try net collections the seed is mainly represented by the size group 41-50 mm for *P. indicus*, 36-50 mm for *P. semisulcatus*, 16-35 mm for *M. dobsoni*, 21-35 mm for *M. affinis* and 21-30 mm for *M. monoceros*.

SEED CALENDARS

January

1. *Physical conditions of the backwater*—Clear water; stray patches of decaying weeds here and there over the surface and nearshore areas but do not pose problems for seed collection.
2. *Salinity*—Ranges from 28.82 to 34.39‰; average, 32.85‰.
3. *Temperature*—Ranges from 27.0 to 29.0°C; average, 28.5° C.
4. *Prawn seeds*—Moderately present. *P. indicus* and *M. dobsoni* are the dominant species; *P. indicus* can be collected in greater numbers by velon screen drag net and *M. dobsoni* by both velon screen drag net and tow net; try net collects relatively poor.

February

1. *Physical conditions of the backwater*—Clear water; surface devoid of weeds but shore and bottom areas harbour plenty of decayed weeds.
2. *Salinity*—Ranges from 32.25 to 33.62‰; average 32.92‰.
3. *Temperature*—Ranges from 29.0 to 30.0° C; average 29.4°C.
4. *Prawn seeds*—Slight improvement in general abundance along the nearshore areas, but remain poor in the plankton as well as deeper waters. *P. indicus* is the dominant species in the velon screen drag net collections.

March

1. *Physical conditions of the backwater*—Clear water; surface and shore completely free of weeds; one of the best months for seed collection by velon screen drag net.
2. *Salinity*—Remains at its peak ranging from 31.11 to 34.80‰; average 33.69‰.
3. *Temperature*—Ranges from 29.8 to 31.0°C, average 30.4°C.
4. *Prawn seeds*—Quite abundant in the nearshore waters but remain poor in other areas as in the previous month. Most of the species represented, dominant being *P. indicus*, *M. dobsoni* and *M. monoceros*; *P. indicus* and *M. monoceros* relatively more abundant in velon screen drag net and *M. dobsoni* in tow net. *P. semisulcatus* occurs commonly in try net.

April

1. *Physical conditions of the backwater*—Clear water; seed collection can be made effectively from all possible parts of the ecosystem.

2. *Salinity*—Ranges from 29.90 to 33.58‰; average 31.08‰.

3. *Temperature*—Ranges from 30.1 to 31.88°C; average 30.7°C.

4. *Prawn seeds*—High abundance continues near the shore, dominant species being *P. indicus*, *M. dobsoni* and *M. monoceros*; *M. affinis* common in try net collections.

May

1. *Physical conditions of the backwater*—Clear water; best season for seed collection like the previous two months.

2. *Salinity*—Ranges from 29.11 to 33.90‰; average 30.63‰.

3. *Temperature*—Ranges from 29.6 to 30.3°C; average 30.0°C.

4. *Prawn seeds*—Peak of general abundance. Dominant species are *P. indicus* and *M. dobsoni*. *P. indicus*, mostly fresh recruits of P_4 to P_{10}, can be collected in enormous numbers by velon screen drag net.

June

1. *Physical conditions of the backwater*—Clear water in the beginning of the month, but becomes turbid afterwards since the freshwater influx begins as a result of monsoon rains.

2. *Salinity*—Ranges from 0.59 to 31.8‰; average 13.01‰; widely fluctuates due to the monsoon rains and flood.

3. *Temperature*—Ranges from 27.1 to 29.5°C; average 28.3°C.

4. *Prawn seeds*—Declines considerably. Important species *P. indicus*, *M. dobsoni* and *M. affinis*; abundance unsteady for most of the species; *M. affinis* occurs in relatively good numbers in the try net collections.

July

1. *Physical conditions of the backwater*—Turbid water due to constant freshwater influx; strong water current; fresh green weeds start infesting the entire ecosystem; not a proper season for seed collection by tow net and velon screen drag net. Try net collections contain enormous quantities of African weed rendering seed sorting laborious.

2. *Salinity*—Remains nearly freshwater ranging from 0.16 to 1.28‰; average 0.38‰.

3. *Temperature*—Ranges from 26.0 to 28.5° C; average 27.0° C.

4. *Prawn seeds*—Generally scarce. Important species *M. affinis* and *M. dobson*. *M. affinis* occurs in peak abundance in try net. Species of the genus *Penaeus* are extremely rare.

August

1. *Physical conditions of the backwater*—Flooded situation and turbidity prevails, but occasionally the water becomes clear. Floating weeds on the surface and nearshore areas and the settled weeds at the bottom make seed collection difficult.

2. *Salinity*—Continues to be very low ranging from 0.16 to 2.71‰; average 0.83‰.

3. *Temperature*—Ranges from 27.3 to 28.8°C ; average 28.0°C.

4. *Prawn seeds*—Continue to be very poor. *M. dobsoni* is the commonly occurring species. Species of the genus *Penaeus* are totally absent. Generally not a good month for seed collection.

September

1. *Physical conditions of the backwater*—Flood continues in lesser intensity; water getting clear and turbidity low; African weeds continue to dictate the ecosystem.

2. *Salinity*—Ranges from 0.92 to 9.15‰; average 2.44‰.

3. *Temperature*—Ranges from 27.4 to 28.8°C; average 28.2° C.

4. *Prawn seeds*—Recolonisation takes place and the system is replenished by a new wave of younger seeds particularly of species of the genus *Penaeus*. *P. indicus* begins to appear in large numbers in the velon screen drag net collections. *M. dobsoni* occurs in peak abundance in both velon screen drag net and try netcatches. Seed collection can be initiated during this month after the monsoon break.

October

1. *Physical conditions of the backwater*—Clear water; the problem of African weed continues.

2. *Salinity*—Gradually rises but unsteady and shows wide fluctuations ranging from 1.19 to 26.76‰; average 15.9‰.

3. *Temperature*—Ranges from 28.4 to 29.0°C; average 28.8°C.

4. *Prawn seeds*—Steadily increases along the nearshore areas, the dominant species being *P. indicus* and *M. dobsoni*. *P. indicus* abundant in velon screen drag net.

November

1. *Physical conditions of the backwater*—Clear water; the floating weeds start decaying; partly decayed weeds get accumulated near the shore and at the bottom hampering the operation of velon screen drag net and try net.

2. *Salinity*—Ranges from 9.86 to 28.28‰; average 20.57‰.

3. *Temperature*—Ranges from 28.0 to 29.4° C; average 28.9°C.

4. *Prawn seeds*—*P. indicus* less abundant than in the previous month; *M. dobsoni* occurs in maximum numbers in the plankton.

December

1. *Physical conditions of the backwater*—Clear water; decayed weeds settle at the bottom and get entangled in try net in large quantities.

2. *Salinity*—Ranges from 24.27 to 29.62‰; average 28.18‰.

3. *Temperature*—Ranges from 27.5 to 29.0°C; average 28.3°C.

4. *Prawn seeds*—General abundance near the shore picks up again with *P. indicus* as dominant species. *M. dobsoni* is fairly common in tow net and velon screen drag net.

Remarks

A perusal of the seed calendar would indicate that although prawn seed is available throughout the year, most of the species have peak seasons of abundance. *M. dobsoni*, the most common species of this backwater, occurs in maximum abundance from August to January, while *M. affinis* and *M. monoceros* have peaks during May-July and December-April respectively. In the case of *P. indicus* the peak occurrence is noticed during the summer period March-May. The seeds of *P. semisulcatus* are relatively more common during January-March and their occurrence coincides with periods of increasing salinity as in the case of *Parapenaeopsis stylifera*.

The information furnished here would be useful in proper seed collection for culture operations. When considering the fast development of intensive shrimp farming around this area, mainly based on the seeds collected from this backwater, a word of caution seems appropriate. Since the juvenile population of penaeid prawns abounding in estuaries and backwaters form the basic stock for replenishing the population in the adjoining inshore waters, their indiscriminate exploitation at the early stages from this nursery area might adversely affect the capture fisheries. Therefore a rational approach is necessary in tapping this valuable resource. For continued progress of prawn culture in this region it is also essential that efforts are intensified for large scale production of quality seeds by artificial propagation. In this context the recent advances made in perfecting techniques of spawning and mass culturing of penaeid prawns under controlled conditions at the Narakkal Prawn Culture Laboratory (Silas and Muthu, 1977) are significant and the efficient methods evolved here will go a long way in establishing hatcheries for large-scale production of seeds to meet the ever increasing demand and thereby reduce the dependence on wild stock.

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RESULTS OF A PILOT SURVEY FOR PRAWN AND MULLET SEEDS AT JODIYA, GUJARAT, INDIA

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ABSTRACT

The paper presents a brief account of the abundance of prawn and mullet juveniles at Jodiya where a brackishwater fish farm is coming up. The results particularly highlight the availability of the seeds during the stocking period of May to July, 1979. It is observed that *Penaeus merguiensis, Metapenaeus brevicornis* and *M. kutchensis* are the dominant juvenile prawns in the creek around the farm site. Juveniles of *Macrobrachium rosenbergii* are also noted in sizable quantity during a restricted period of year.

Abundance of mullet seeds is also studied to use them as a constituent member of polyculture. Ecological parameters such as water temperature, salinity and pH are observed to explore the possibility of correlations with the abundance of juveniles. The study establishes the availability of prawn and mullet juveniles at the doorsteps of the farm.

INTRODUCTION

A BRACKISHWATER fish farm at Jodiya in the Gujarat State is being constructed under Central assistance, with an aim to establish prawns and mullets rearing under controlled conditions and to demonstrate to the fishermen and entrepreneurs of the coastal area the potentialities of brackishwater fish farming. This farm will be the first of its kind in Gujarat. For any fish culture the basic requirements are to find out the abundance of required species of juveniles near the farm site and their periods of availability. Patel *et al.* (1978) have made preliminary observations of the seed resources in this area. Except for this work no data are available for this region.

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MATERIALS AND METHODS

For the seed collection, the creeks of river Uand and Aji were selected nearby Jodiya and Ranjitpar respectively (Fig. 1). Shooting net (10 m length × 3 m width × 1½ m height having 1/20" mesh size) was operated in the middle of the creeks. The net was kept for 10 minutes against the current and then removed. Separation of the catch was made species-wise. 50 juveniles were kept in plastic buckets of 10 litre capacity. About 40% of the juveniles were composed of prawn, 2% of mullet and the remaining of miscellaneous juveniles comprised of clupeids, perches and puffer fish. After segregation, prawn juveniles

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were transferred to a small nursery (50′ × 20′) for acclimatization and rearing. Along with seed collection, hydrological perameters such as salinity, pH and water temperature were also recorded. Shooting net was operated during high and low tides throughout the month.

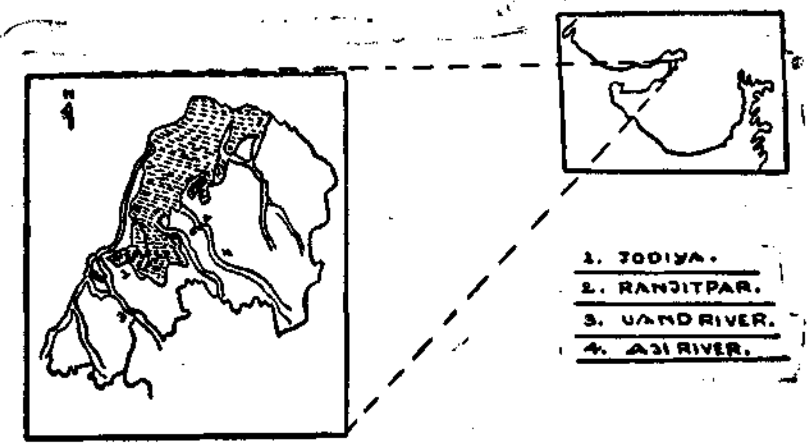

Fig. 1. Map showing the locations of the survey.

Observation and Discussion

Availability of different species of prawn and mullet juveniles is noted throughout the year. In March and April, seeds of *Macrobrachium rosenbergii* and *Metapenaeus kutchensis* are predominant. Whereas during the months of May to July, mainly three species of prawns viz. *Penaeus merguiensis*, *M. brevicornis* and *M. kutchensis* dominate the prawn seed catch (Table 1). Maximum availability of seeds is noted in the first 30 minutes of the incoming tide, whereas very few were caught during the receding tide. The tidal influence on abundance of prawns seed was also observed during May to July (Table 2). Good numbers were recorded during the tides in full moon and new moon periods (15 *SUD* and 15 *VAD**), whereas their numbers were less in the half moon days (7 *SUD* and 7 *VAD*).

* Hindu calendar days.

Salinity remained between 30‰ to 39‰ during May to July in Uand river creek, but in the Ranjitpar creek, salinity was always found to be high between 45‰ to 65‰, probably on account of seawater crossing vast salty areas and salt production centres.

In the present survey only *M. kutchensis* was recorded in the Ranjitpar area.

Water temperature also fluctuated between 29°C to 37°C with a maximum of 37°C. It was observed that when water temperature went beyond 35°C, the numbers of *P. merguiensis* and *M. brevicornis* decreased, whereas that of *M. kutchensis* increased (Table 2).

Average size increase noted during May to July was 5.3 cm to 6.7 cm and 3.1 cm to 4.1 cm in *P. merguiensis* and *M. brevicornis* respectively. In *M. kutchensis* the size recorded was between 4.2 cm to 4.7 cm. It is assumed that *M. kutchensis*, may require low salinity for growth. Low salinity is available only during the post-monsoon period in this region. This could

TABLE 1. *Abundance of prawn and mullet seed during the stocking period (May to July 1979) at Jodiya brackishwater fish farm*

Month	Availability in high tide										
	Water quality			Collection of prawn and mullet seed/net/hour in Number and size (cm)							
				P. merguiensis		*M. brevicornis*		*M. kutchensis*		Mullets	
	Salinity ‰	pH	Temp. °C	Number	Average size	Number	Average size	Number	Average size	Number	Average size
May	38.0	7.7	30.0	541	5.3	420	3.1	750	4.52	24	4.2
June	37.7	7.8	33.8	296	5.6	787	3.1	1834	4.2	133	4.8
July	35.0	8.0	29.8	204	6.7	1057	4.1	1048	4.72	258	6.2

TABLE 2. *Influence of tide on abundance of prawn seed during the stocking period (May to July 1979) at Jodiya brackishwater fish farm*

Month	Hindu calendar	Availability in high tide								
		Water quality			Collection of prawns seed/net/hour in number and size (cm)					
					P. merguiensis		*M. brevicornis*		*M. kutchensis*	
		Salinity ‰	pH	Temp. °C	Number	Average size	Number	Average size	Number	Average size
May	VAD-7	38.0	7.8	30.0	390	5.0	428	3.15	918	4.27
	VAD-15	38.0	7.8	30.0	646	5.0	342	3.21	586	4.19
June	SUD-15	39.0	7.5	33.0	682	6.2	1590	3.0	1800	4.4
	VAD-7	38.0	7.9	37.0	112	5.0	450	2.8	2887	3.9
July	VAD-15	30.0	8.5	29.0	210	7.2	1447	4.32	1515	5.2
	SUD-7	39.0	8.0	29.0	195	5.95	1627	4.1	1147	4.89

be one of the reasons for their slow growth during the period mentioned. In the present studies it was also noted that *M. kutchensis* was the only species in this region having wide salinity and temperature tolerance range (Table 2).

Experience indicates that the most suitable period for prawn seed collection is before monsoon. During the monsoon the creeks near river Uand and Aji are flooded and the collection operations become difficult.

Juveniles of culturable prawns such as *P. merguiensis* and *M. brevicornis* are regularly available near the farm site making it easy to stock the farm.

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OBSERVATION ON SEASONAL ABUNDANCE OF PRAWN SEED IN SHETRUNJI ESTUARY AT SARTANPUR, GUJARAT, INDIA

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Abstract

A survey of prawn seed resources by shooting net operations in Shetrunji estuary, Sartanpur (Gujarat), indicated the dominance of postlarvae of *Penaeus indicus* and *Metapenaeus monoceros*. In August 1978, *P. indicus* and *M. monoceros* seeds were collected at an average rate of 13256/hour and 8652/hour respectively. However, the occurrence in 1977 during the same period was considerably low. Presence of the juveniles of *M. brevicornis*, *Palaemon styliferus* and *Macrobrachium rosenbergii* in the estuary was also noteworthy. An attempt was made to correlate the abundance of prawn seed with the temperature and salinity of the estuarine water and rainfall data of the area.

Introduction

Importance of the study of availability and abundance of fast growing prawn seeds in capture and culture fisheries is well established (Subrahmanyam, 1967; Subrahmanyam and Rao, 1969; Jhingran *et al.*, 1970). Gopalakrishnan *et al.* (MS) have made a primary survey of prawn and fish seed availability at Sartanpur in Bhavnagar district of Gujarat. On the basis of this, an intensive study of prawn juvenile abundance around Shetrunji estuary has been undertaken as a step prior to developing a prawn culture farm at Sartanpur, Gujarat State by Fisheries Department, Government of Gujarat. In this paper the comparative results of shooting net operations in August 1977 and August 1978 in the area are particularly highlighted.

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Material and Methods

Shooting net is reported to be more efficient than other gears for catching the postlarval prawns (Subrahmanyam and Rao, 1969; Gopalakrishnan *et al.*, MS.). In the present study a shooting net of 362 cm × 180 cm × 83 cm size mosquito net body and 88 cm × 55 cm malmal cloth receptacle was operated for 30 minutes in the mouth of estuary during incoming tides twice a day generally for five days during fullmoon period.

Temperature and salinity were measured by standard methods. Tidal readings were taken by fixing graduated wooden guages in the creek and on the adjoining intertidal areas.

Results and Discussion

The results of the survey for prawn postlarvae and juveniles, by shooting net, at

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Sartanpur, in August 1977 and August 1978 are particularly highlighted being very noteworthy due to postmonsoon environment providing near optimum situations in which a mix of marine as well as fresh water prawns and fishes are available. Table 1 shows some of the physico-chemical conditions at Sartanpur during the period under review.

TABLE 1. *Some physico-chemical conditions at Sartanpur Estuary*

Parameter	August, 1977	August, 1978
Tidal Range (in m)	0.99- 1.35	0.99- 1.35
Salinity (‰)	0.99-26.29	6.53-33.75
Temperature (°C)—Air	25.00-31.00	25.5 -31.0
-do- —Water	25.0 -30.0	25.0 -32.0
Rainfall (in cm)	119.0	159.0

The results of shooting net operation during the fullmoon period in August of 1977 and 1978 showed the presence of fish as well as prawn seeds and fingerlings. Fries and fingerlings of *Mugil parsia*, *M. cunnesius*, *M. tade*, *Beleophthalmus* sp., *Puntius* sp. and eel made up about 40% catch in 1977, while it was only a meagre portion (less than 0.5%) in the total catch in 1978.

Prawn seeds comprised of *Penaeus indicus*, *Metapenaeus monoceros*, *Palaemon styliferus*, *M. brevicornis* and *Macrobrachium rosenbergii*. The catch sometimes also contained juveniles of the mud crab, *Scylla serrata*.

In 1977, *M. monoceros* seeds dominated (67.7%) followed by *P. styliferus* (21.9%), *P. indicus* (10.0%) and *M. brevicornis* (0.4%). While in 1978, it was *P. indicus* which made up major portion (60.4%), of the prawn seeds caught, followed by *M. monoceros* (39.5%) and *P. styliferus* (0.1%).

A very remarkable outcome of the present study was availability of unusually large number of seeds of *P. indicus* and *M. monoceros*—46395 and 30282 respectively—during five days of fullmoon period of August 1978. Subrahmanyam and Rao (1969) also reported such incidence of *P. indicus* postlarvae in unusually large numbers during day collection on fullmoon day in March, 1967 at Pulicat Lake, but at Sartanpur this phenomenon was common for *P. indicus* as well as *M. monoceros*. The catch was generally more during night time, similar to that reported by Ganapati and Subrahmanyam (1964), Bearden (1961), Williams (1959), Subrahmanyam and Rao (1969) and Subrahmanyam and Ganapati (1971).

Average collection rate of *P. indicus* was a meagre 4.8 per hour dominated by 16-25 mm size group in 1977, in comparison to 13255.7 per hour dominated by 4-7 mm size group in 1978. Gopalakrishnan *et al.* (MS) recorded peak collection rate of 94.8 *P. indicus* postlarvae per hour in March-April at Sartanpur, while Subrahmanyam and Rao (1969) reported peak collection rate of 13275 per hour during September 1967 at Pulicat Lake. Evangeline and Sudhakar (1973) have found 6 mm *P. indicus* postlarvae totaling 35% (sometime upto 80%) of total prawn postlarvae recruited in Adyar estuary and Mohamed and Rao (1971) have also found *P. indicus* postlarvae to enter estuary at an advanced stage measuring 7.0 mm.

In 1977, collection rate of *M. monoceros* seeds was 32 per hour dominated by 46-55 mm size group while in 1978 it was as high as 8652 per hour dominated by 4-10 mm size group, as in the case of *P. indicus*. Earlier Gopalakrishnan *et al.* (MS) have indicated the highest collection rate for *M. monoceros* seeds to be 351.3 per hour in April-May.

Rajyalaxmi (1973) reported 0 — group (23-60 mm) juveniles of *P. styliferus* in Hooghly-Matlah and Roopnarain Estuaries almost throughout the year. Bhanot (1971) has mentioned that *P. styliferus* postlarvae were available during December-March in Matlah estuary around Port Canning. At Shetrunji estuary they were available during August of 1977 as well as 1978 at a rate of 10.4 per hour, dominated by 26-45 mm size group and 24.3 per hour, dominated by 16-25 mm size group, respectively.

Present results also agree with Bearden (1961) Subrahmanyam (1967) and Subrahmanyam and Rao (1969) that prawn fries are available in more numbers near the mouth of estuary or creek.

Sreekumaran Nair and Krishnankutty (1975) found that the growth rate of *P. indicus* was significantly high in low salinity for postlarval specimens, but the larger juveniles showed a significantly high growth rate in high saline waters. Rao (1973) reported abundant *M. monoceros* postlarvae in 5.0-9.9‰ and 20.0-24.9‰ salinity while temperature had no apparent relationship with distribution of prawn larvae, while several workers (Rajyalaxmi, 1973) have correlated rainfall with prawn yields. Gopalakrishnan *et al.* (MS) mentioned that prawn juveniles were more abundant during the months of low temperature but there was no correlation with the salinity. The unusually high abundance of prawn postlarvae, in August 1978, at Sartanpur, may have some correlation with higher maxima of salinity and temperature and the significantly high rainfall during that period.

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PENAEID PRAWN POPULATION AND FRY RESOURCE IN A MANGROVE SWAMP OF GOA, INDIA

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ABSTRACT

Penaeid prawns abundantly occur in the mangrove swamp during the premonsoon season. They are constituted by the commercial species, *Penaeus merguiensis*, *Metapenaeus dobsoni* and *M. monoceros*. Recruitment to the swamp takes place when the individuals are between 10 and 20 mm in size. Growth rate and period of stay in this environment vary with species. About 46.5% of the population is comprised of juveniles ranging in size from 10 to 30 mm. These could be collected in large numbers between December and June for aquaculture purposes.

INTRODUCTION

UNCERTAINTY in the availability of natural seed prawns is one of the major constraints in the success of commercial shrimp culture. Many countries of the Indo-Pacific region where shrimp culture has been practised traditionally have succeeded in large scale hatchery production of penaeid prawn fry and have thus overcome this obstacle (Milne, 1972; Pillay, 1972; Ling, 1977). A large portion of the natural prawn seed is being collected from the brackishwater environments making good use of their entry into these environments for their early development. Various aspects of penaeid prawn larval migration into the estuaries of Goa have been studied (Achuthankutty, *et al.*, 1977; Selvakumar, *et al.*, 1977). It was felt that vast areas of mangrove swamps bordering the Mandovi-Zuari estuarine complex may provide a potential site for seed prawn collection. Hence a year-round study was made in an ideal swamp to assess the prawn seed resource and other related aspects which are summarised in this paper.

The authors are thankful to Dr. S. Z. Qasim and Dr. T. S. S. Rao for the facilities and encouragement.

MATERIAL AND METHODS

The study was conducted in a low lying mangrove swamp (15°31′N, 73°48′E) (Fig. 1). The swamp opens to the mouth of the Mandovi estuary and hence is tide fed. Monthly samples were taken during low tide by hauling a rectangular net (mesh size 5 mm) through the bottom from June 1978 to May 1979. Penaeid prawns were identified and total length (tip of rostrum to tip of telson) was measured.

RESULTS

Occurrence and Composition: During the course of the study only three species of penaeid prawns were collected from this swamp. They were *Penaeus merguiensis* de Man, *Metapenaeus dobsoni* (Miers) and *M. monoceros* (Fabricius). Their percentage occurrence was 22.32, 42.66 and 35.02 respectively. About 60% of the total catch was made during the premonsoon season (February-May) and a mere 16% during the postmonsoon season (October-January). Monsoon season (June-September) accounted for the rest of the catch. Species abundance also showed more or less a similar pattern of variation.

Recruitment : Recruitment to the mangrove swamp was taking place when the individuals were between 10 and 20 mm in size as this was the smallest size range of all these species occurring in the swamp. However, individuals belonging to 20-30 mm size group were also being recruited in small numbers in certain months as can be seen from Fig. 2. Year-round recruitment was taking place only in *M. dobsoni*. Recruitment which was at a slow pace during the postmonsoon months in all the species, intensified during the pre-monsoon months and gradually declined during the monsoon months. Total absence of 10-20 mm size group of *P. merguiensis* and *M. monoceros* during the monsoon season indicates that recruitment of these species was not occurring during this season.

Growth : Growth was studied by length-frequency method. Progression of modes was traced from 10-20 mm in all the species. *M. dobsoni* attains a maximum size of 50-60 mm in 5 to 6 months, whereas *M. monoceros* stays in this environment for 7 to 8 months and attains a relatively larger size of 70-80 mm (Fig. 2). *P. merguiensis*, on the other hand, grows to 80-90 mm in a relatively short span of 6 to 7 months (Fig. 2). Nevertheless, due to overlapping of modes, the tracing of the progression of modes was difficult in certain months. This might happen in tropical species having slow growth or prolonged breeding or a combination of both (Qasim, 1973).

Fig. 1. Study area.

Juvenile population : About 46.5% of the penaeids was constituted by individuals of the

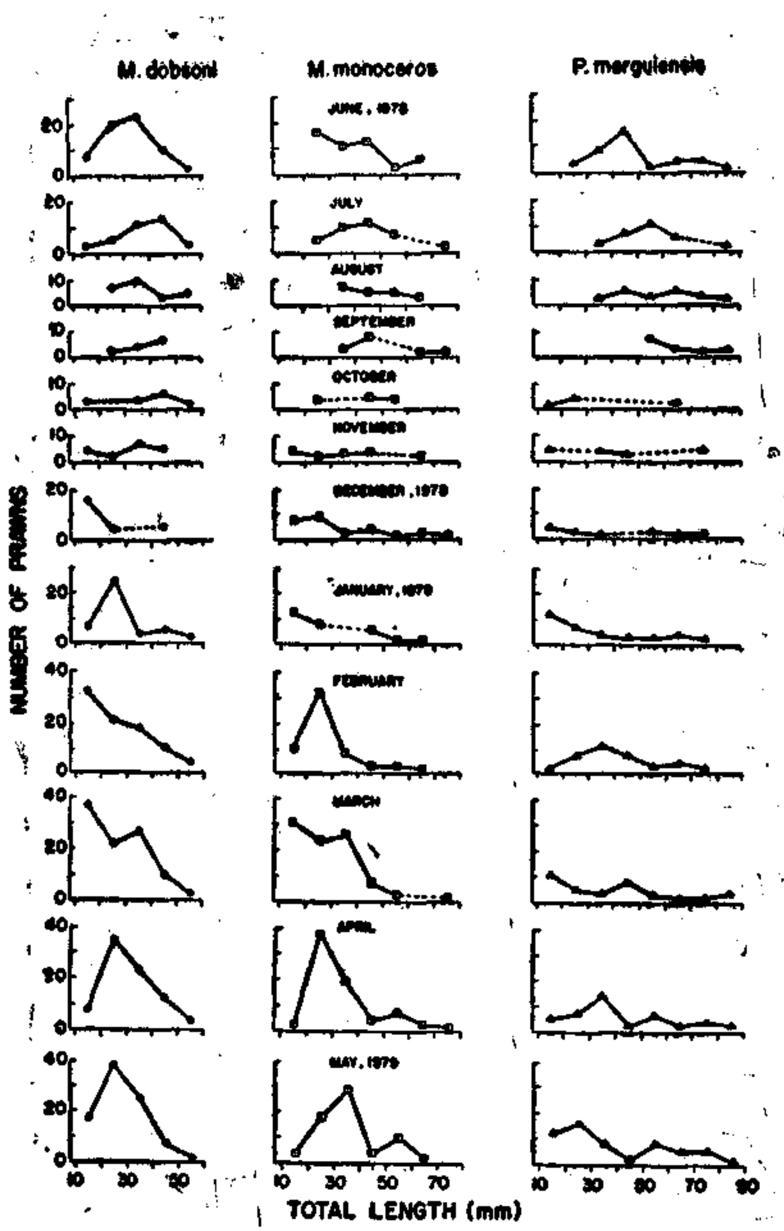

Fig. 2. Progression of modal length in successive months in different species of penaeid prawns.

size group 10-30 mm. Of this, the percentage contributions of *P. merguiensis*, *M. dobsoni* and *M. monoceros* were 15.3, 49.2 and 35.5 respectively. The maximum juvenile population (10-30 mm) was recorded during the premonsoon season (Fig. 3). Average number of *M. dobsoni* juveniles collected during this season was 10,175/ha and that of *P. merguiensis* and *M. monoceros* was 3,000/ha and 7,625/ha respectively. Juveniles of the latter two species were totally absent in the swamp during the latter half of the monsoon season. Juveniles which appeared in small numbers in October progressively increased to attain the maximum abundance during the premonsoon season and declined drastically or was completely absent during the monsoon months.

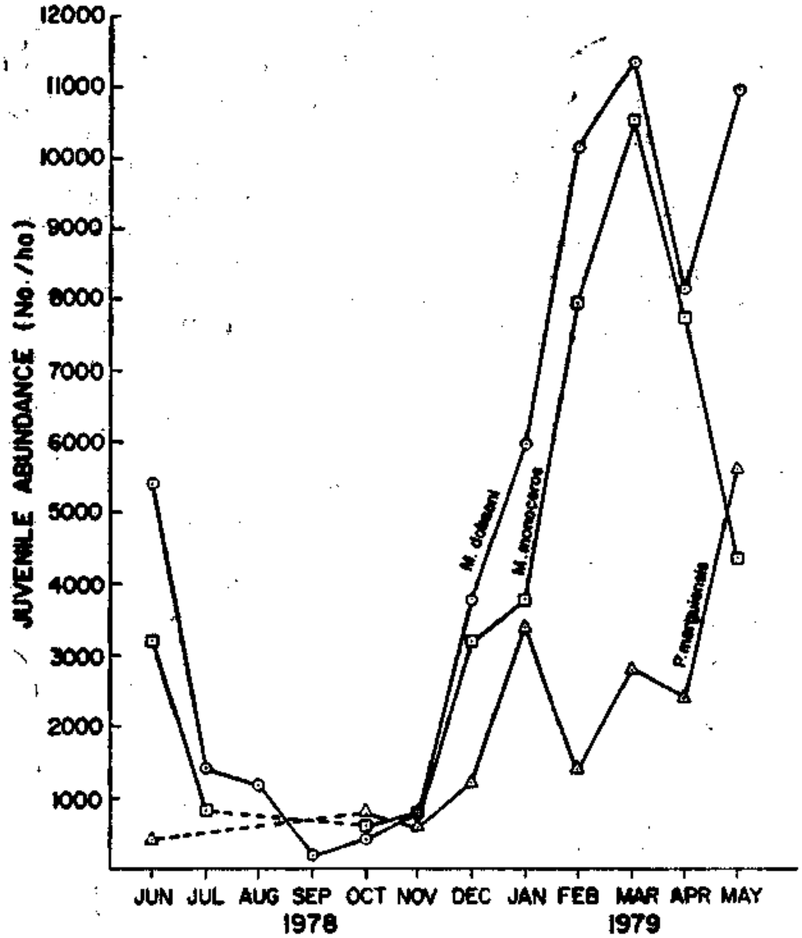

Fig. 3. Variation of juvenile population of *M. dobsoni*, *M. monoceros* and *P. merguiensis* in different months.

Discussion

The species under investigation form the bulk of penaeid prawn landing from Goa coast. These species are known to breed in inshore waters (George, 1962, 1970 a, b; Rao, 1968, 1972; George and Goswami, 1977; Goswami, *et al.*, 1977) and their postlarvae enter the estuaries and backwaters for early development (George, 1962, 1968; Kutkuhn, 1966; Gunter, 1967; Achuthankutty, *et al.*, 1977). A large portion of the postlarvae of these species which enter the estuaries, soon after attaining the juvenile stage may migrate to the nearby mangrove swamp as evidenced by the initial size of the recruited individuals. It is also likely that most of the postlarvae may grow to juvenile size immediately after their entry into the estuaries (Selvakumar, *et al.*, 1977) and hence a rich population of juveniles could be expected in the swamps which are directly connected to the estuarine mouth. Intense recruitment of the juveniles occurs during the succeeding months of their peak spawning reported from the coastal waters of Goa (Achuthankutty *et al.*, 1977; George and Goswami, 1977).

A combination of different conducive factors for faster growth make this specialised ecosystem an ideal nursery ground for these marine prawns. These swamps are tide fed and the salinity is relatively low. Large quantities of food in the form of organic aggregates are available here (Snedaker, 1978). Fine silty mud substratum and abundance of mangrove foliage offer suitable cover for these juvenile prawns to bury. Absence or less number of predators and harmful creatures provide necessary protection in the most critical growing stage.

Martosubroto and Naamin (1977) have emphasized the need for the proper management of these tidal forests for commercial shrimp production and Snedaker (1978) has listed the factors responsible for their growth and propagation in this environment. Goa has vast stretches of potentially rich mangrove swamps which are the natural nursery grounds of the penaeid prawns which have an estuarine phase in their life-cycle. Hence, the exploitable yield of the juvenile prawns from their nursery ground should be properly assessed before commencing large scale collection for aquaculture. Overexploitation of juveniles would have far-reaching consequences on the commercial shrimp production. So also, utmost care should be taken to manage this specialised ecosystem for the conservation of penaeid prawn fishery.

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PRAWN AND FISH SEED RESOURCES OF MARAKANAM ESTUARY

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Abstract

Data collected during 1977 and 1978 on the availability of fish seed in Marakanam Estuary indicated that it has adequate seed potential of culturable prawns and fishes. The seed survey was conducted by operating nylon shooting nets and velon drag nets. Among prawns, the seeds of *Penaeus indicus*, *Metapenaeus monoceros*, *M. dobsoni*, *P. semisulcatus* and *P. monodon* in that order of abundance were encountered. The seeds of mullets and milk fish predominated in the fish seed population of the estuary. Information on species-wise occurrence, and their seasonal and spatial distribution pattern of the prawn seeds in the estuary and suitable gear for collection is presented and discussed.

Introduction

Utilisation of brackish water areas for the production of prawn and fish has increased considerably in the recent years and consequently there is a growing demand for the seeds of cultivable species of prawns and fishes for stocking in grow-out ponds. Lack of information on the naturally available seed resources of cultivable species of prawns and fishes is one of the main constraints in the development of brackish water prawn and fish farming. This communication deals with the investigations carried out on the seed resources of commercially important species of prawns and fishes of the Marakanam estuary in South Arcot District, Tamil Nadu State during the year 1977 and 1978.

The authors are thankful to Shri C. Chellappan, Director of Fisheries, Government of Tamil Nadu and Dr. A. V. Natarajan, Director, Central Inland Fisheries Research Institute and Co-ordinator of the Project for their guidance and encouragement in the study.

Material and Methods

Marakanam River (otherwise called Kazhuveli River) takes its origin from Kazhuveli Tank, situated in Tindivanam Taluk of South Arcot District (Fig. 1). The tank is mainly fed by north-east monsoon. Land drainage during monsoon periods is collected in the tank and drained through the river, which joins with the sea, Bay of Bengal, by the side of ruins of Alamparva Fort. A regulator constructed on the river just below the tank prevents the mixing of salt water with the fresh water above the regulator. The tidal fluctuation is felt up to this regulator, which is at a distance of 18 km from the mouth. On both sides of the upper reaches of the estuary, extensive salt pans are located.

A Midnapore type standard spawn collection net (Nylon) (Jhingran *et al.*, 1970) was used for the study. Monthly collections were made by operating the net near the mouth of the estuary for two hours during spring high water (either full or new moon phase). Depending upon the variations in the topography of the estuary near the mouth, nature of the bar, tidal waves and force of the wind, the net had to be shifted from one place to another to find a suitable location for fixing and operating the net. However, throughout the period of study, the net was operated within a distance of 500 m from the mouth. In addition, one velon drag net of 2 × 1 × 0.5 m (7 meshes/cm) was operated at four stations (Fig. 1). Monthly hauls of 30 minutes duration were taken from the four stations for a total period of 22 hrs during 1977 and 24 hrs during 1978. No observation could be made during November 1977 due to heavy floods in the estuary.

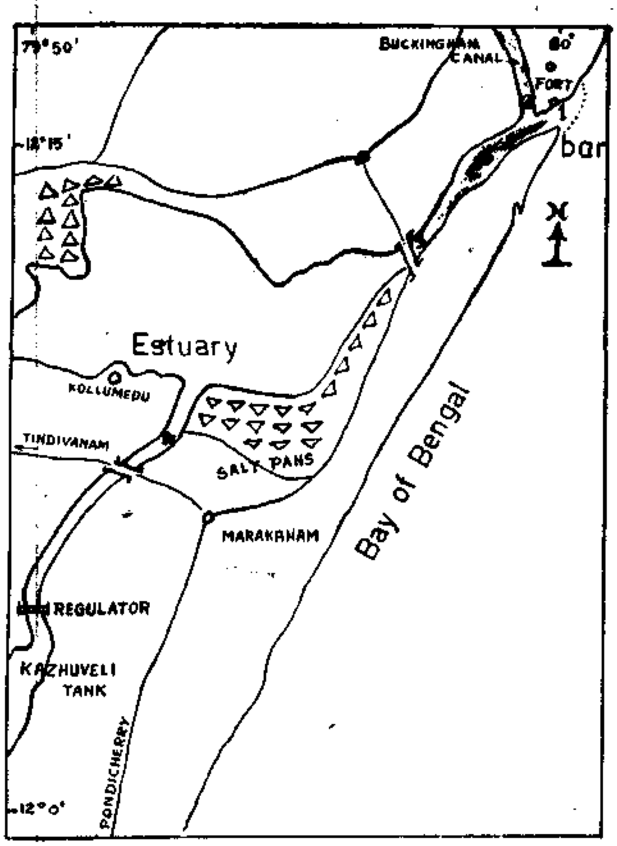

Fig. 1. Map of Marakanam Estuary showing location of stations.

Shooting net collections were made near the mouth (Station 1) for 44 hours during the period from January '77 to December '78.

The various species of commercially important prawns and fishes in the collections were numerically estimated. Water temperature, salinity, pH and dissolved oxygen of the water were recorded at the time of collection.

Observations and Results

The hydrological data collected at the four stations are given in Table 1.

Total catch

Fig. 2 shows the monthly average catch/number/hour (c/n/hr) during the year 1977 and 1978. It could be observed that the ingression of prawn and fish seeds into the estuary was at its maximum during January to May, August and September with peaks in January, March, May, August and September. It was earlier observed that January to June was the most productive period in Bakkali area (Basu and Pakrasi, 1979). Bose *et al.* (1980) recorded maximum ingression of prawn larvae in Adyar estuary during January to May and August and September. At Pulicat Lake, peak ingression of prawn larvae was observed in April, July and December (Gopinathan, 1978).

Species composition

The percentage occurrence of commercially important prawn and fish seeds in the Marakanam estuary during 1977 and 1978 are given in Table 2. The overall percentage composition of the commercially important species for the said period in order of abundance was *Penaeus indicus* 36.34%, *Metapenaeus monoceros* 9.65%, mullets (mainly *Mugil cephalus*, *M. parsia*, and *Lizza macrolepis*) 9.27%, *Metapenaeus dobsoni* 6.1%, *P. semisulcatus* 3.21%, *P. monodon* 2.17%, and *Chanos chanos* 1.39%, miscellaneous fishes forming 31.87%. The miscellaneous fishes were represented mainly by *Anchoviella* sp., *Therapon* spp., *Hemirhamphus* sp., *Triacanthus* sp., *Etroplus* spp., *Ambassis* sp., *Gerres* spp., *Elops* sp., *Megalops* sp., *Cynoglossus* sp., *Pseudorhombus* sp., *Siganus* spp., *Sphyraena* sp., *Leiognathus* spp., *Anadontostoma* sp. and elvers of eels.

TABLE 1. *Hydrological variations of Marakanam Estuary*

	STATIONS 1	2	3	4
Surface water temperature (°C)	25.9-31.8	24.2-31.5	26.4-32.8	25.6-32.4
pH	7.2-8.4	7.3-8.4	7.2-8.6	7.0-8.5
Dissolved oxygen (ppm)	6.47-9.20	6·39-8.48	6.09-9.08	6.12-8.79
Salinity (ppt)	2.79-35.48	1.94-33.64	1.23-34.82	0-30.47

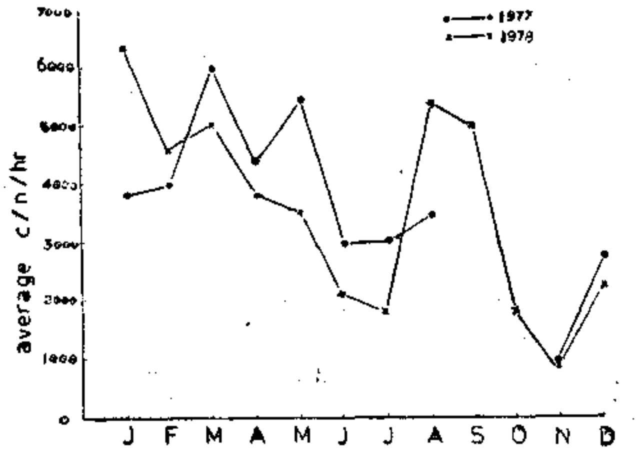

Fig. 2. Average monthly catch of prawn and fish seeds during 1977-78.

TABLE 2. *Year-wise percentage composition of commercially important prawns and fishes*

Species	YEAR 1977 (%)	1978 (%)	Overall average (%)
Penaeus indicus	32.76	39.92	36.34
P. semisulcatus	2.79	3.64	3.21
P. monodon	2.46	1.88	2.17
Metapenaeus monoceros	8.27	11.02	9.65
M. dobsoni	5.86	6.34	6.10
Mullets	11.34	7.21	9.27
Chanos chanos	1.50	1.28	1.39
Others	35.02	28.71	31.87

Seasonal abundance

The seasonal variations in abundance of various groups of prawn and fish seed are presented in Fig. 3. The ingression of postlarvae of *P. indicus*, *P. monodon*, *M. monoceros* and *M. dobsoni* and fry of mullets was observed throughout the year, whereas the recruitment of the postlarvae of *P. semisulcatus* was limited to the period from January to September; the fry of *Chanos* from March to June and September to November. The peak availability of the commercially important species were January, February, July to September and December for *P. indicus*; March to June for *P. semisulcatus*; May, August, October to December for *P. monodon*; January, April to June, August and December for *M. monoceros*; May to August and December for *M. dobsoni*; April, May and September for *Chanos* and January to March and October for mullets.

Spatial distribution of seeds

Species-wise overall average c/n/hr at the four stations during 1977 and 1978 are shown in Fig. 4. Congregation of seeds varied from station to station. Among all the stations the total catch from station 4 was comparatively poorer.

Of the various species of prawns, *P. indicus* formed the bulk of the catch in all the stations. *P. monodon*, though available at all the stations, its contribution ranged from 2.3 to 7.1% of the total catch. *P. semisulcatus* was predominant at Station 1 and a descending order of abundance towards the upper reaches of the estuary was observed. They were almost absent in station 4. Metapenaeids were uniformly abundant in all the stations, contributing to 11.69% to 17.22% of the total catch. Among fishes, mullets represented in the collection at all the stations. They were numerically abundant at station 2. Congregation of *Chanos* fry was better in stations 2 and 3 and 4. At station 4 they contributed to 14.27% of the total catch.

Discussion

Postlarvae and early juveniles of *P. monodon* were abundant in places with macrovegetations and shallow regions with plenty of organic debris on the bottom. Bose *et al.* (1980) observed the congregation of *P. monodon* seeds in shallow margins with plenty of marginal weeds. Similarly, places with macrovegetations and seaweeds formed the habitat of postlarvae and juveniles of *P. semisulcatus*. A simple washing of the weeds was sufficient to collect them. The preference of weeds by *P. semisulcatus* was observed in Pulicat Lake (Gopinathan, 1978), and Vellar estuary (Subramanian *et al.*, 1980).

The present observation confirms the view of Bose *et al.* (1980) that of *P. indicus* appeared to prefer shallow margin with soft sand and debris. The abundance of *P. indicus* in Buckingham Canal area (Station 2) which is shallow, with soft sand and lot of organic matter in the bottom further confirms this view. They were also abundant in abandoned salt pans and shallow pools with considerable organic matter.

It was observed that the recruitment of *P. semisulcatus* was directly related to the salinity values of the estuary. Increase in salinity values during January (after the monsoon) marked the appearance of *P. semisulcatus*, and the maximum values in March-June coincided with the peak availability of these seeds. Their absence in the upper reaches of the estuary (Station 4) may also be attributed to the low values of salinity.

The seasonal abundance and distribution pattern of *P. indicus* and *P. monodon* revealed that they were able to tolerate wide variations in salinity. *P. monodon* had been encountered in salinity values of 1.3 to 2.0‰.

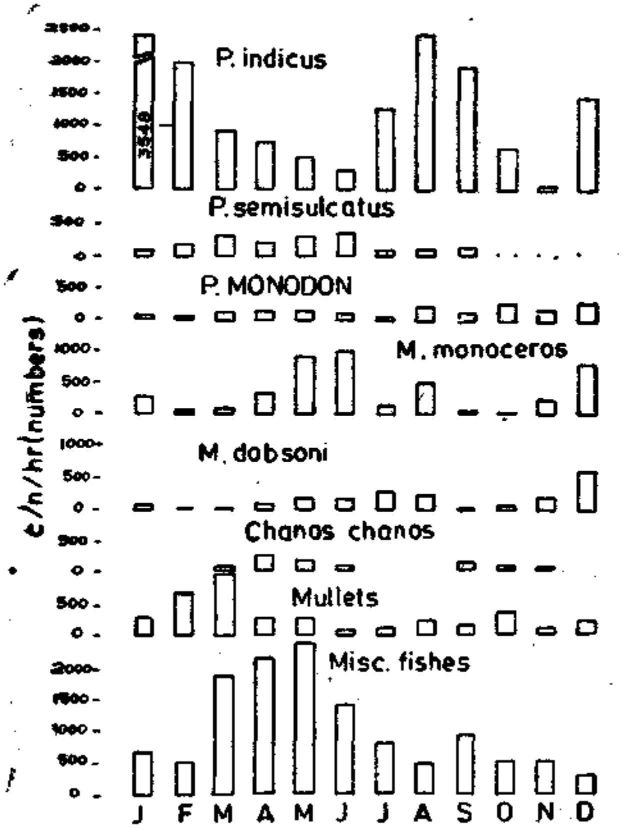

Fig. 3. Seasonal variations in the abundance of prawn and fish seeds during 1977-78.

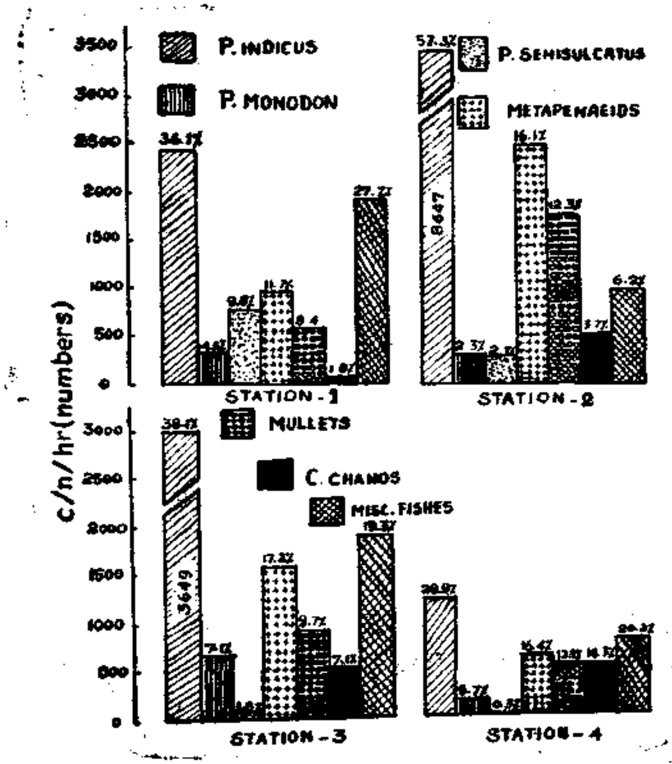

Fig. 4. Species-wise average catch from the four stations in the Marakanam Estuary during 1977-78.

It was observed (Bose *et al.*, 1980) that shooting net was efficient in trapping postlarvae of prawns and it could be operated in places where tidal current would be sufficient. The bottom should also be shallow, smooth and gently sloping for operating the net. The present observations confirmed this view. Moreover strong winds and tidal waves near the mouth prevented the operation of the net. The usefulness of this net lies in its efficiency in trapping postlarvae of prawns and early fry of mullets and *Chanos*. Segregating the different species of prawn and fish in the collection would be extremely difficult because of their smaller size. However, *P. monodon* could be easily segregated from other species. The collections of this net could give an idea of the recruitment of various species of prawns and fishes into the estuary during various seasons.

For collecting large number of seeds for stocking in ponds, velon drag net would be efficient. It could be operated in all shallow margins, and stagnant pools in the estuary where prawn and fish juveniles generally abound with. However, this net is not suitable for the collection of fingerlings of fish especially mullets which swim fast and escape from being caught by the net.

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FOOD OF SOME PENAEID PRAWNS RELATIVE TO THEIR CULTURE IN BRACKISHWATER PONDS OF SUNDERBANS

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ABSTRACT

The food of penaeid prawns, *Penaeus indicus* H. M. Edwards, and *P. monodon* Fab., in the length range of 21-120 mm and metapenaeid prawns, *Metapenaeus monoceros* (Fab.) and *M. brevicornis* (H. M. Edwards) in the length range of 21-100 mm cultured in brackishwater ponds was studied. The major food of these prawns consisted of Bacillariophyceae or diatoms, Myxophyceae or blue-green algae, crustaceans and plant parts in the order mentioned.

In *P. indicus*, Bacillariophyceae (53.48-83.43 %), plant parts (1.25-26.92 %) and crustaceans parts (1.26-17.74 %) constituted the main food. In *P. monodon*, Bacillariophyceae (43.78-95.87 %) formed main food upto the size of 80 mm while plant parts (2.28-44.0 %) and the Myxophyceae (1.43-26.0 %) were observed in the stomach contents of the specimens ranging from 21 to 120 mm size. Crustaceans (semi digested) parts were found as food item of prawns of the size of 60 mm and above.

Consumption of Bacillariophyceae were observed to be maximum both in *M. monoceros* and *M. brevicornis* forming 54.03-83.74 % and 31.0-60.71 % of food materials for the above species respectively. Among the next items, plant parts (11.50-31.29 %) for *M. monoceros* and crustaceans parts (12.20-31.99 %) for *M. brevicornis* constituted the major portion of food.

Thus, the study indicated that the above species of penaeid and metapenaeid prawns feed actively both on vegetative and animal organisms.

INTRODUCTION

OF THE SEVERAL species of penaeid and metapenaeid prawns available in the estuaries of Sunderbans, *Penaeus indicus* H. M. Edwards, *P. monodon* Fab., *Metapenaeus monoceros* (Fab.) and *M. brevicornis* (H. M. Edwards) occupy the place of importance in brackishwater culture.

Consequent on the increasing demand of these species of prawns in the international market, more and more attention is being paid for improving the technology of culture to produce more prawn in unit time and space. Food being one of the important parameters to determine the growth and survival, an understanding of the food of these species of prawns at different stages of growth under culture conditions is of vital importance. With this view the food of the above species of prawns was studied while conducting culture experiments in brackishwater ponds at Kakdwip.

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of Kakdwip Research Centre for their keen interest in the work.

Materials and Methods

The materials for the present study were collected from Brackishwater Fish Farm of Kakdwip during the period of January, 1976 to April, 1979 and consisted of 150 specimens of *P. indicus*, 120 specimens of *P. monodon*, 130 specimens of *M. monoceros* and 125 specimens of *M. brevicornis* in the size range of 21-120 mm for *P. indicus* and *P. monodon* and 21-100 mm for *M. monoceros* and *M. brevicornis*.

Specimens were preserved in 5% formalin and later on sorted out into 20 mm size groups. The stomach contents of all the specimens in a size group were collected together in a watch glass and different items of food were sorted out under a microscope following the process of drop method as suggested by Pillay (1956).

Observations

The data on percentage volume of various items of food consumed by different size groups of the prawns of the species studied are presented in Table 1a and Table 1b.

It can be seen from the Tables that in general the diatoms constituted the major food item for all the species of prawns studied.

In *P. indicus*, the diatoms, *Pinnularia* sp. and *Navicula* sp. followed by *Cymbella* sp., *Cocconeis* sp., *Synedra* sp. formed the maximum portion of food. Next items of importance were plant parts, crustacean parts and desmids.

In case of *P. monodon*, blue-green algae and plant parts were observed to form the usual food for all size groups of the prawn. Diatoms constituted the food for the size groups of prawns ranging from 21 to 80 mm only whereas crustacean parts alongwith debris were observed in stomach contents of prawns ranging from 61 to 120 mm size. Other items like desmids, rotifers and polychaete worms were only occasional food for the prawns.

Food of *M. monoceros* were observed to be somewhat different from those of other prawns discussed above. In this prawn, diatoms comprising of *Navicula* sp., *Cymbella* sp. and *Amphora* sp. and plant parts constituted the main food.

In *M. brevicornis*, although diatoms formed the major food of the species but crustacean parts alongwith detritus also formed the bulk of it.

Discussion

The observed food of the above species of prawns cultured in brackishwater ponds at Kakdwip in Sunderban region differ from that of prawns collected from natural sources. Gopalakrishnan (1952) found vegetable matters, crustaceans like copepods, ostracods and amphipods; molluscan shells; polychaete worms, echinoderm larvae, hydroids and trematodes constituting the major food of *P. indicus*. Food items such as ostracods, molluscan shells, amphipods, hydroids and echinoderms were not at all met with in the stomach contents of the prawns under present study.

Hall (1962) observed the food of *P. monodon* collected from natural sources as well as ponds. Polychaetes, small and large crustaceans constituted the food of the prawns collected from natural sources whereas only small crustaceans were observed by him in the stomach of prawns collected from culture ponds. Caces-Borja and Rasalan (1968) observed the food of the fry of the species collected from prawn cultivating ponds in Philippines to be comprised of 'Lab-lab', an association of small plant and animal organisms. The above observations on the food of pond prawns by Hall (1962) and Caces-Borja and Rasalan (1968) agree

TABLE 1 a. *Percentage composition of food of* P. indicus *and* P. monodon *cultured in brackishwater ponds*

Size groups (mm)	*P. indicus* 21-40	41-60	61-80	81-100	101-120	*P. monodon* 21-40	41-60	61-80	81-100	101-120
Food items										
Bacillariophyceae or diatoms ..	76.33	83.43	53.48	55.05	64.52	71.92	95.87	43.78	—	—
Myxophyceae or blue-green algae ..	—	—	10.00	41.19	—	22.50	1.43	23.67	23.00	26.00
Desmids ..	8.15	0.99	5.62	1.25	—	—	2·70	1.55	—	—
Plant parts ..	9.14	6.89	26.92	1.25	17.74	2.28	—	14.00	20.00	44.00
Rotifers ..	0.48	—	0.22	—	—	—	—	—	—	—
Protozoans ..	0.11	—	—	—	—	3.30	—	—	—	—
Polychaete worms ..	—	—	—	—	—	—	—	4.00	—	—
Crustacean parts with detritus	5.79	8.69	3.73	1.26	17.74	—	—	13.00	57.00	30.00

TABLE 1 b. *Percentage composition of food of* M. monoceros *and* M. brevicornis *cultured in brackishwater ponds*

Size groups (mm)	*M. monoceros* 21-40	41-60	61-80	81-100	*M. brevicornis* 21-40	41-60	61-80	81-100
Food items								
Bacillariophyceae or diatoms ..	83.74	67.38	54.03	65.50	37.00	60.71	31.00	49.70
Myxophyceae or blue-green algae ..	—	18.28	14.23	—	—	—	17.10	12.50
Desmids ..	4.76	1.52	2.00	—	2.78	15.28	—	—
Plant parts ..	11.50	12.82	18.50	31.29	—	—	24.30	33.60
Rotifers ..	—	—	—	—	9.76	4.67	—	—
Protozoans ..	—	—	2.32	—	18.47	—	2.00	2.00
Crustacean parts with debris ..	—	—	8.92	3.21	31.99	19.84	25.60	12.20

with our observations that the diatoms and blue-green algae which are generally found in algal mats of prawn ponds form the main food of the prawns.

George (1974) studied the food of *M. monoceros* and found as omnivorous in feeding habit. Crustaceans such as amphipods, isopods and copepods ; polychaete remains ; vegetable matters like angiosperm tissues and diatoms, foraminifera, molluscan shell pieces and detritus were the major items of food. In the present study, however, diatoms and plant parts were observed as main food of the prawn. Hall (1962) studied the food of 40 specimens of *M. brevicornis* of which 23 were from day light fishing operations in Malacca Straight and 17 from night fishing from Singapore prawn pond and classified the species as feeding mainly on vegetable matter. The main food in order of abundance were angiosperm tissues and filamentous algal materials, small crustaceans like copepods, echiurid setae, remains of large crustaceans and fish and polychaetes. Sand grains were also observed in most of the specimens. However, the foods of prawns studied from brackishwater prawn ponds at Kakdwip in Sunderban region indicated diatoms and crustaceans to be the major food items of the species.

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A REGRESSION MODEL FOR THE PREDICTION OF AVAILABILITY OF *PENAEUS MONODON* FABRICIUS SEED

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ABSTRACT

A multiple regression model for the prediction of the availability of *Penaeus monodon* Fabricius seed was developed by analysing the catch data of the seed collected from the Muriganga estuary near Kakdwip Research Centre during 1976-1978. In the regression model, catch (per net-hour) was correlated with water temperature, salinity and total suspended solid. Correlation between catch and transparency and dissolved oxygen were found to be non-significant. In fitted multiple regression model the analysis of variance was performed to test the significance of regression co-efficients where the salinity, water temperature and total suspended solid were observed to be highly significant. The regression co-efficients of the variates, transparency and dissolved oxygen were found to be non-significant and hence excluded from the model. The relative importance of the factors in predicting catch of *P. monodon* seed is presented and discussed.

INTRODUCTION

PRAWN CULTURE in India depends mainly upon naturally available seed for stocking. A knowledge of the availability and peak period of abundance of various species of prawn postlarvae are a must for formulating a successful selective prawn culture operation. Information on the prawn seed availability of the various estuarine systems in India such as Hooghly-Matlah estuary (Chakraborty *et al.*, 1977; Gopalakrishnan and Rao, 1968; Jhingran *et al.*, 1970; Rao and Gopalakrishnnan 1968; Ravishchandra, 1962; Verghese *et al.*, 1979, Subrahmanyam and Rao, 1972; Karmakar *et al.*, 1979), Chilka lake (Kemp, 1915; Jhingran and Natarajan, 1970), Godavari estuary (Subrahmanyam, 1964, 1965; Subrahmanyam and Ganapati, 1971), Pulicat lake (Rajendran and Sampath, 1975; Rao, 1973; Subrahmanyam and Rao, 1968), Adyar Estuary (Evangaline, 1969; Evangaline and Sudhakar, 1972) and Cochin Backwater (Kuttyamma, 1975; Kuttyamma and Antony, 1975; Mohamed, 1970; Rao, 1972) have been reported. These reports generally deal with the availability and seasonal abundance of the prawn postlarvae. Verghese *et al.*, (1979) attempted to correlate the abundance of *Penaeus monodon* Fabricius postlarvae with salinity and temperature of ambient water in Muriganga Estuary. Though *P. monodon* is a continuous breeder, the availability of the postlarvae fluctuates to a great extent according to the changes in the physico-chemical factors of the environment. An attempt has been made in the present study to connect five different water quality parameters (temperature, salinity, total suspended solid, transparency and dissolved oxygen) with the catch of *P. monodon* post-larvae/net/hour data by fitting a multiple regression

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model and to predict the availability of *P. monodon* postlarvae from such a model.

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Materials and Methods

The prawn seed were collected by operating standard Midnapore type of shooting net (320 cm length × 310 cm bredth × 60 cm at mouth) of 1/8" mesh size in the Muriganga estuary during 1976-78 for one hour for one day during each spring tide. The collection were removed from the tail piece once in half an hour and brought to the field laboratory for manual segregation of *P. monodon* postlarvae as per the technique discussed elsewhere (Verghese *et al.*, 1979). The number of postlarvae collected by the net were recorded as catch/net/hour. Simultaneously water samples were collected and temperature and turbidity recorded. Salinity, dissolved oxygen and total suspended solid were analysed as per standard methods (A.P.H.A., 1965). A total of 49 samples were collected and analysed in the study.

For the regression model the correlation between catch (no./net/hour) of *P. monodon* postlarvae with each of the variables, water temperature, salinity, total suspended solid, transparency and dissolved oxygen were calculated. Only the correlation between the catch and water temperature, salinity and total suspended solid were found significant and the level of the significance varied between 5% to 0.1%. Although correlation between catch and turbidity and dissolved oxygen were found non-significant at 5% level, they were also included in the model along with the significant variables to connect with the catch by a multiple regression model :

$$Y = b_0 + b_1 x_1 + b_2 x_2 + b_3 x_3 + b_4 x_4 + b_5 x_5$$

Where Y = Catch (no./net/hour) of *P. monodon* seed

x_1 = Water temperature (°C)

x_2 = Salinity (ppt)

x_3 = Total suspended solid (gms)

x_4 = Transparency (mm)

x_5 = Dissolved oxygen (ppm)

The multiple regression model was fitted to the data by the method of least square and the normal equations was solved with the help of a desk calculator. The significance of the regression co-efficients were tested using analysis of variance techniques. Also the relative importance of each of the variables mentioned in the prediction equation was calculated using the formula :

$$b_{i} \times \sqrt{\Sigma x_i 2 / \Sigma y_i 2}$$ (Snedecor and Cochran, 1967).

Results and Discussion

From the normal equations the regression co-efficients b_0 to b_5 were calculated. The equation of the fitted regression was $Y = -6550.27285 + 205.69198x_1 + 164.71845x_2 + 485.95702x_3 - 4.61529x_4 + 19.47794x_5$.

Significance of the regression co-efficients was tested by F-test and the analysis of variance was presented in Table 1. From the table it is evident that the sum of square due to regression was found to be highly significant at 1% level. But the significance of the individual b's were tested by 't' test where $t = bi/SE\sqrt{Cii}$ and Cii are the elements of Inverse matrix.

TABLE 1. *Analysis of variance*

Source	Degress of freedom	SS	MS.S.	F
Due to regression	5	95725145.32	19145029.06	10.275*
Deviation from regression	43	80113443.68	1863103.34	
Total	48	175838589.00		

* Significant at 1% level.

The regression co-efficients b_1 (t=4.2569, 43 d.f.), b_2 (t=15.8926, 43 d.f.) and b_3 (t=2.3238, 43 d.f.) were found to be highly significant. But the co-efficients b_4 (t=0.7974, 43 d.f.) and b_5 (t=0.1680, 43 d.f.) were found to be non-significant and hence the variables, transparency and dissolved oxygen have been excluded from the model. The new model thus becomes

$$Y=b_0+b_1x_1+b_2x_2+b_3x_3$$

Where Y, x_1, x_2 and x_3 have usual meanings. By solving the normal equations in usual way the regression co-efficients b_0 to b_3 of the new model were claculated. The equation of the fitted regression was

$$Y=-6207.5128\pm185.1930x_1+153.7306x_2+535.9532x_3$$

Analysis of variance of the significance of these regression co-efficients was presented in Table 2. From this table it could be seen that the regression co-efficients are all significant at 1% level indicating that fitted model is capable of explaining a significance part of the variability in the catch of the seed of *P. monodon*. The fitted regression model could explain only 52% of the variability. Though

TABLE 2. *Analysis of variance for testing significance of fitted regression model*

Source	Degress of freedom	SS	MS.S	F
Regression	3	92618568.86	30872856.27	16.694*
Deviations	45	83220020.14	1849333.78	
Total	48	175838589.00		

* Highly significant at 1% level.

TABLE 3. *Relative importance of the variables included in the new regression model*

Variables	Relative importance
Salinity	0.4704
Water temperature	0.4074
Total suspended solid	0.2840

five main variables of water was studied, still a large part of the variability could not be explained by the regression model evolved from these variables. Some more important variables such as tidal amplitude, velocity of water current and primary productivity were not taken into account in this study. For a better prediction model, the above variables should also be studied along with temperature, salinity and total suspended solid.

The relative importance of the variables included in the regression model is presented in Table 3. It is evident from the table that the salinity is a prominent factor in the prediction of catch followed by water temperature and total suspended solid, which confirms the earlier observations (Verghese *et al.*, 1979; Kuttyamma, 1975).

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FORMULATION OF CHEAP PRAWN DIETS AND THEIR BIOLOGICAL EVALUATION ON SOME PENAEID PRAWNS

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ABSTRACT

While using the cheap locally available wastes and raw materials, two compound diets have been formulated and prepared. Three species of penaeid prawns *viz. Metapenaeus monoceros, M. affinis* and *Penaeus indicus* were fed on these diets in the laboratory for their biological evaluation. The essential features of a shrimp diet such as the physical stability in water and its ingestion rate at different time intervals are also discussed.

INTRODUCTION

THE FORMULATION of cheap prawn diets is of paramount importance to the commercial venture of prawn culture. This can be achieved by utilizing and experimenting upon a variety of locally available low-priced raw materials. Goswami and Goswami (1979) had reported the good nutritive value of slaughter house waste like beef liver discarded for human use on veterinary grounds, coconut oil cake, etc. and advocated their use in formulation of compound prawn diets. The present communication deals with laboratory experiments of two such diets prepared and tested for their physical stability, ingestion rate and biological efficiency before undertaking them for field trials.

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MATERIALS AND METHODS

Two dry pelleted diets (A and B) were prepared utilizing slaughter house waste (beef liver discarded for human use), coconut oil cake, soya flour, mangrove leaves, wheat flour and distilled water in different amounts (Table 1). The details of methodology of forming the feed is as described elsewhere (Goswami and Goswami, 1979). The per cent bio chemical composition of the major nutrients are given in Table 2. The diets were labelled A and B.

TABLE 1. *Composition (%) of different ingredients in diet A and B*

Ingredient	Diet A	Diet B
Slaughter house waste	30	45
Coconut oil cake	10	15
Soya flour	20	20
Mangrove leaves	10	5
Wheat flour	35	20
Distilled Water	40	60

Three series of experiments were designed to find out (1) the water stability of the diets in different salinities of sea water (5, 10, 20, 30 and 35 ‰) after 18 hours, (2) effect on the rate of ingestion after feeding intervals of 3, 5, 18 and

48 hours to the prawn *Metapenaeus monoceros* and (3) a comparative studies on growth rate and food conversion ratios in *M. monoceros*, *M. affinis* and *Penaeus indicus* fed upon the two prepared diets and the control diet C frozen fish flesh).

TABLE 2. *Total (%) biochemical composition of major nutrients in the diets A and B*

	Diet A	Diet B
Protein	33.58	42.241
Carbohydrates	8.73	11.64
Lipids	15.62	15.03

The general environmental conditions were kept uniform for all the experiments *e.g.* size of tanks (45 × 23 × 30 cm.) ; depth of water (12 cm), temperature (28.5 ± 1°C), aeration (30-50 bubbles) and photoperiod (12 hours). The experimental animals for series 2 and 3 (32-42 mm size) were collected from a fish farm in Old Goa. These were acclimatized for a week to the test diets and then kept without food for 24 hours prior to initiating new experiments. In both the series number of replicates (1) and animals (10/tank) were also kept the same. Experiments of series 3 lasted for 30 days. The other details of methodology and computation of data were after Balazs *et al.* (1973), Sick *et al.* (1972) and Venkataramiah *et al.* (1975) for series 1, 2 and 3 respectively.

RESULTS

The results of our first series of experiments with diet A and B in different salinities of seawater showed that loss of dry weight after 18 hours was more for diet B and the values decreased gradually with an increase in the salinity (Table 3).

For second series of experiments pertaining to the ingestion rate after 3, 5, 18 and 48 hours, it was found that diet A showed better results than diet B in all time intervals except for the initial 3 hours (see Table 3). However, the maximum value was noticed after 5 hours (65.6) which continuously decreased (15.0 after 48 hours).

Results of the third series of experiments conducted showed that all the animals survived till the end of the experimental period. They fed well and showed increase in length and wet weight. For all the species length gain was maximum with diet C. However, amongst the prepared diets, diet A showed better results almost approaching to that of diet C. Wet weight gain in species of *Metapenaeus* was in the order of diet C, B and A whereas with *P. indicus* diet A showed the maximum values.

TABLE 3. *Dry weight loss (%) of the two diets in different salinities of sea water kept for 18 m. (200 mg of feeds were added to each salinity)*

Salinities (‰)	Diet A	Diet B
5	6	16.90
10	3.5	15.15
20	2.52	13.55
30	..	8.85
35	..	..

Diet A when fed upon *M. monoceros*, *M. affinis* and *P. indicus* gave food conversion ratios (FCR) as 3.078, 7.19 and 1.54 respectively. Similarly, diet B showed the highest ratios in *M. affinis*, and lowest in *P. indicus* (Table 5). But diet C, showed highest to lowest values in the order of *P. indicus*, *M. affinis* and *M. monoceros*.

DISCUSSION

Due to the intermittent feeding behaviour of the prawns, good water stability of any compound diet is a highly desirable feature (New, 1976). In the first series of experiments

TABLE 4. *Ingestion rate/hour* of diet A and B by juvenile* Metapenaeus monoceros
(Values are given in mg diet on dry weight basis)

Time (T) in hours	3		5		18		48	
	1a**	Control	2a	Control	3a	Control	4a	Control
Diet A								
Initial wt (M i)	106	106	329	329	650	650	850	850
Final wt (M f)	100	106	..	328	60	647	90	810
Wt loss in water (Md)		..	..	1	..	3	..	40
Ingestion rate/hour	2	..	65.6	..	32.6	..	15.0	..
	1b	Control	2b	Control	3b	Control	4b	Control
Diet B								
Initial wt (M i)	106	106	329	329	650	650	850	850
Final wt (M f)	48	100	137	319	201	609	100	734
Wt loss in water (Md)	..	6	..	10	..	41	..	116
Ingestion rate/hour	17.33	..	36.4	..	22.66	..	13.20	..

* Ingestion rate/hour (I) $= \frac{Mi-Mf-Md}{T}$ (after Sick *et. al.*, 1973).

** 1-4 as a & b are the number of tanks used for diet A and B respectively.

TABLE 5. *Per cent length, wet weight gain and food conversion ratios* for* Metapenaeus monoceros, M. affinis *and* Penaeus indicus *fed upon diets A and B and C (Control). The experiment period was* 30 *days*

Diets	*M. monoceros*			*M. affinis*			*P. indicus*		
	Length	Weight	FCR	Length	Weight	FCR	Length	Weight	FCR
A	23.46	25.06	3.078	14.78	11.07	7.19	7.33	41.64	1.54
B	9.42	33.73	2.33	12.22	22.53	3.71	7.20	27.33	1.64
C	24.38	34.77	1.92	17.78	31.18	1.93	15.64	32.36	2.72

* FCR=Dry food consumed/live wt gain.

the lower water stability of diet B as compared with diet A is probably due to the different composition of wheat flour and distilled water. Balazs *et al.* (1973) have explained in detail the physico-chemical reactions involved in such circumstances. The decrease in the dry weight loss with an increase in salinity suggests the use of common salt while preparing compound diets. Gunter and Venkatramiah (1975) had included a preferable concentration of sea water in a patented shrimp diet, as mentioned by New (1976).

Water stability and ingestion rate of the diet are two inter-related factors. This is further ascertained from second series of our experiments where diet A with good stability has shown better ingestion rate after 5, 18 and 48 hours. The lowest value in the initial 3 hours is probably due to the hard texture of the diet thereby hindering in the masticatory process. New (1976) has reviewed the importance of optimum moisture content in the prawn diets.

Data on growth rates and food conversion ratios on various species of panaeid prawns have earlier been published by Andrews *et al.* (1972), Venkataramiah *et al.* (1975) and Royan *et al.* (1977). Royan *et al.* (1977) have reported FCR values ranging between 0.94-3.50 when *M. monoceros* was fed upon different levels of protein. However, the results of all these earlier workers are not directly comparable to the present case due to different diets, species, size of animals and other environmental parameters involved; each of which has a varying effect on the food conversion efficiency (New, 1976). Since high FCR values shows the low food conversion efficiency, from third series of present experiments it can be derived that diets A and B have shown best food conversion efficiency on *P. indicus* and lowest on *M. affinis*. It further suggests that good efficiency of a diet shown on one species cannot be taken for granted to be the same in other species also. This becomes more clear as we think of the inherent differences amongst species as a natural biological phenomenon (Bishop, 1966).

In conclusion it may be said that while undertaking field trials with the diets A and B, a combination of the two given on subsequent days will probably show better results since in the traditional type of prawn culture ponds in India, the stocking is not selective, so many species grow together at the same time. Keeping in view the ingestion rate, the frequency of feeding diet A once per day and diet B twice per day will be sufficient to maintain better quality of water.

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EFFECTS OF STARVATION AND OF ALGAE-FEEDING ON THE TISSUE CHOLESTEROL LEVELS IN COMMERCIAL SHRIMP *PENAEUS AZTECUS* IVES

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Abstract

Tissue lipid and cholesterol contents of brown shrimp *Penaeus aztecus* Ives were compared in the laboratory among starved individuals and those fed green algae *Ulva lactuca* and *Enteromorpha* sp. or a pelleted diet. Cholesterol levels were found to vary with size, sex, and diet.

Shrimp fed the pelleted diet showed an increase in cholesterol content with increased body weight. The females showed a greater hepatopancreatic mass and higher cholesterol content in muscle, eyes, and hepatopancreas than males fed the same diet. The eyes contained the most cholesterol of all tissues tested ; the level increased linearly in males but geometrically in females. Hepatopancreatic cholesterol level increased linearly with size in females but remained essentially unchanged in males. Muscle cholesterol increased linearly as body weight increased among females, whereas males maintained a steady level independent of size.

Starvation reduced the body weight and hepatopancreatic cholesterol level of both sexes while levels in other tissues remained essentially unchanged. The shrimp which fed on green algae *U. lactuca* and *Enteromorpha* sp. had significantly reduced cholesterol levels in the muscle, hepatopancreas and blood. The levels in the eyes were not modified by algae-feeding.

Extrapolating these relationships, it is suggested that the bulk of marketable shrimp (60-68 whole shrimp/lb) have relatively lower cholesterol levels than is reported in nutritional and medical literature. It appears that the smaller the shrimp, the lower its cholesterol content will be. Only 'jumbo' shrimp (30 or less whole shrimp/lb) showed a value close to the reported value. Compared to caviar, organ meats, brains and eggs, shrimp muscle shows a low cholesterol content.

Introduction

Nutritional (USDA, 1963 ; USDA, 1971 ; Feeley *et al.*, 1972) and medical (Scrimshaw, 1975) literature report the presence of high cholesterol levels in shellfish, including shrimp. These values are relatively higher than those of lean cuts and fish. There is now unifying evidence that many crustaceans utilize cholesterol for their normal growth and survival (Castell *et al.*, 1975) but individually cannot synthesize the molecule from simple precursors like acetate or mevalonate (Zandee, 1962 ; Whitney, 1969 ; Teshima and Kanazawa, 1971). Kanazawa *et al.* (1971) added evidence to show that sterols of the Japanese prawn are of exogenous origin, probably accumulated through diet. Many dietary factors of plant origin have been shown to be associated with cholesterol metabolism in vertebrate tissues and to cause significant hypocholestemia (Cooper *et al.*, 1960 ; Scrimshaw, 1975). The omnivorous brown shrimp *Penaeus aztecus* Ives feeds on algal and plant material even when food of animal origin is abundant in the vicinity (Venkataramiah *et al.*, 1977). It would be interesting to note whether such behaviour affects the natural cholesterol content of brown shrimp.

This report compares the distribution of cholesterol in the tissues of shrimp fed on a compounded diet with those fed algae for two weeks and with animals starved for two weeks. This analysis reveals the effects of feeding level and schedule on the tissue cholesterol content of brown shrimp. The pelleted diet provides the nutritional requirements of the shrimp and serves as the optimized control in these invstigations. In addition, the study on the distribution and level of cholesterol and total lipids in the tissues of commercial brown shrimp *P. aztecus* Ives supplements existing information on the nutritional value of brown shrimp.

We wish to thank Dr. Gordon Gunter, Director Emeritus, Gulf Coast Research Laboratory for his encouragement and Mrs. Sharon Wilson Christmas for typing the manuscript.

Material and Methods

Brown shrimp *P. aztecus* Ives were trawled from Davis Bayou Ocean Springs, Mississippi during August and September 1977 and maintained in the laboratory as described by Venkataramiah *et al.* (1977). They were fed a pelleted diet (35.6% protein), formulated in the Physiology Section of the Gulf Coast Research Laboratory (Gunter and Venkataramiah, 1975) for 45 days; fish meal was the main protein source. The pellets contained 1.157 mg cholesterol per g dry mass. A batch of shrimp was maintained in a separate tank and deprived of food and algae for 2 weeks at which time they were sacrificed for the experiments. Another batch was left in a tank containing two species of brackishwater green algae, sea lettuce *Ulva lactuca* and *Enteromorpha* sp. As and when the animals consumed the algae, fresh material was added to the tank for a period of two weeks until the animals were used for experimentation.

Total lipids were extracted from the whole shrimp as well as from various individual tissues by the method of Bligh and Dyer (1959). Only intermolt shrimp were used for analyses. The tissue was weighed, minced, and homogenized in a tissue grinder; the 3 β-sterols were extracted in an acetone-alcohol mixture (1 : 1) using 10 ml per g tissue. The supernatant was separated by centrifugation at 1500 g in an IEC PR-J centrifuge and the sterols precipitated with digitonin (Sigma Co.) after saponification of the extract. The precipitate was collected by centrifugation at 1500 g, purified by repeated washings with acetone-alcohol, and subjected to the Liberman-Burchard color reaction (Sperry and Webb, 1950) using a photo-electric colorimeter. Cholesterol (Sigma Co.) was used as the colorimetric standard. The digitonide was dissolved in pyridine and subjected to silicated thin layer chromatography (TLC) to check purity of the sterols. The plates were developed in petroleum ether-diethyl ether-acetic acid (85 : 15 : 1) and the spots were visualized by charring at 105°C after being sprayed with 6N H_2SO_4. Further analysis of sterols by GLC was not done because it is known that cholesterol constitutes 95-98% of total sterol in penaeid shrimp (Thompson, 1964).

Statistical analyses were done on an IBM 1130 scientific subroutine package and the 't' statistics computed following the formula given by Sokal and Rohlf (1969).

Results

The TLC studies indicated that the extracted sterol resembles the authentic sample of cholesterol confirming the earlier reports (Thompson, 1964) that shrimp sterols are cholesterol. Fig. 1 illustrates the changes in total lipids with reference to body weight. An increase in body weight caused an increase in the lipid content of the shrimp. Lipid accumulation in the tissues in relation to body weight was curvilinear. Large females showed

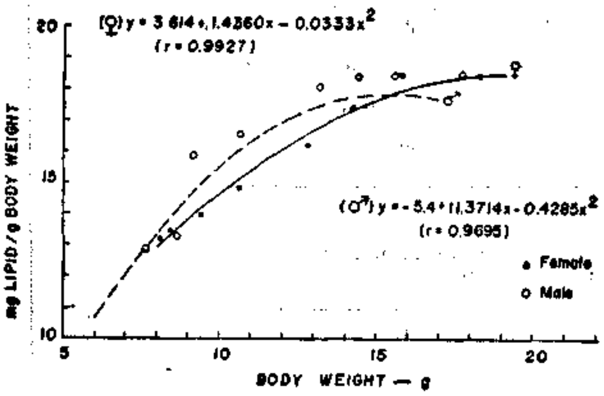

Fig. 1. Total lipid in relation to body weight of shrimp *P. aztecus* fed on pelleted diet.

relatively greater lipid content than males of the same size. The tissue lipid content showed sex-dependent variations (Table 1). Females of 12.5 g mean body weight showed significantly higher ($p < 0.001$) lipid content in the muscle, eyes and hepatopancreas than males. No signfiicant sex-related differences were noticed in the gills or exoskeleton. These data indicate that lipid stores are restricted to certain tissues.

The lipid content of the hepatopancreas was greatest of all the tissues examined (Table 1). Eyes (which included eyeball and eyestalk) contained more lipid than the abdominal muscle tissue (Tables 1, 2). The weight of the hepatopancreas increased non-linearly with reference to body weight (Fig. 2); the increase was greater among females than males.

Table 2 gives the relative distribution of cholesterol in the tissues of shrimp with reference to sex. The eyes contained the most cholesterol and the exoskeleton the least. Although females had a larger hepatopancreas and a greater lipid store in it, the cholesterol content of the female hepatopancreas was significantly less than that of males.

Table 3 presents a comparative account of the effects of starvation *vs.* feeding on the pelleted diet on the cholesterol content of shrimp. In order to detect the effects of starvation on size of the shrimp, the experiment was started with similarly-sized individuals (of a uniform length and weight). After two weeks of starvation, the shrimp were found to measure the same length but they had a relatively lower body weight. The starved individuals lost 16.04% of the initial weight in case of males but only 10.91% in the case of females. In both sexes the cholesterol content of the blood and abdominal muscle did not alter on a unit wet weight basis. However, there was a significant decrease in the hepatopancreas after starvation. It can be concluded from these

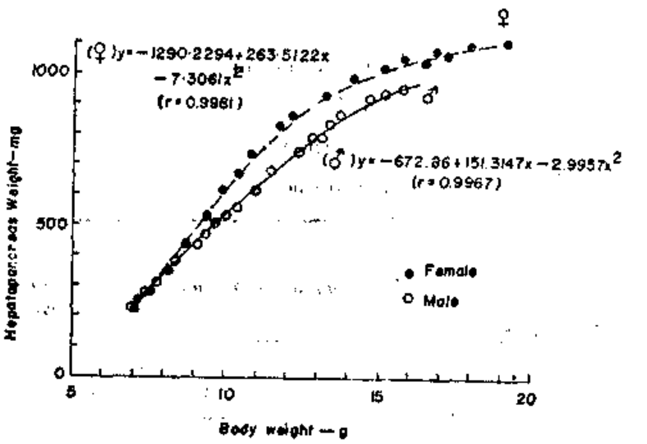

Fig. 2. Body weight and hepatopancreas weight relationship in shrimp *P. aztecus* fed on palleted diet.

data that starvation mobilizes the cholesterol levels of the hepatopancreas in both sexes.

Figs. 3 to 6 illustrate the variations of cholesterol contents with reference to algae-

TABLE 1. *Lipid content in intermoult shrimp* Penaeus aztecus *fed on a pelleted diet. Mean body weight* 12.5 *g*.

Tissues	Lipid content (mg/g tissue)—$\bar{X}\pm$ S.D.			
	N	Male	Female	't'
Muscle	4	6.82± 0.52	8.38± 0.31	5.15
Eyes	5	48.64± 1.24	54.49± 2.34	4.94
Hepatopancreas	5	49.32± 2.46	62.72± 1.64	10.13
Gills	5	17.86± 1.88	19.46± 0.96	1.69
Exoskeleton	5	3.18± 0.28	3.39± 0.17	1.96

TABLE 2. *Cholesterol levels in tissues of intermoult shrimp* Penaeus aztecus *fed on a pelleted diet. Mean body weight* 10.3 *g*

Tissue	Cholesterol (mg/g tissue)	
	Male	Female
Blood	0.15	0.34
Eyes	5.47	4.69
Heart	1.72	1.81
Gills	1.82	1.78
Gut (and contents)	2.66	1.79
Muscle	1.59	1.05
Exoskeleton	0.22	0.23
Hepatopancreas	1.38	0.79

TABLE 3. *Comparison of cholesterol levels in brown shrimp* Penaeus aztecus *between fed controls and shrimp starved for two weeks*

Test Shrimp	N	Post-test Length (mm)	Post-test Weight (g)	Cholesterol (mg/g tissue)—$\bar{X}\pm$ S.D.		
				Muscle	Blood	Hepatopancreas
Fed (male)	6	114± 3	10.97± 0.38	1.56± 0.18	0.34± 0.08	1.21± 0.11
Starved (male)	5	113± 4[a]	9.21± 0.43[b]	1.38± 0.07[a]	0.29± 0.09[a]	0.88± 0.07[b]
Fed (Female)	4	130± 2	17.13± 0.23	1.52± 0.16	0.24± 0.05	0.92± 0.03
Starved (Female)	6	131± 3[a]	15.26± 1.01[b]	1.41± 0.08[a]	0.23± 0.04[a]	0.81± 0.08[b]

a No change compared to fed control ($p > 0.001$).
b Reduction in weight compared to fed control ($p < 0.001$).

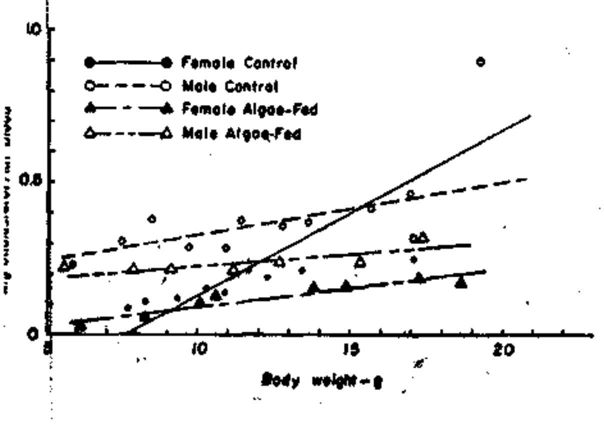

Fig. 3. Variations in the cholesterol content of blood of *P. aztecus* in relation to body weight. Regression equations : Male control y=0.1589+0.017x, r=0.8409 ; Male algae fed y=0.1482+0.0078x, r=0.8237 ; Female control y=0.0535x−0.3984, r=0.8051 ; Female algae fed y=0.012x−0.0237, r=0.9239. No significant differences between slopes of control and algae fed were found.

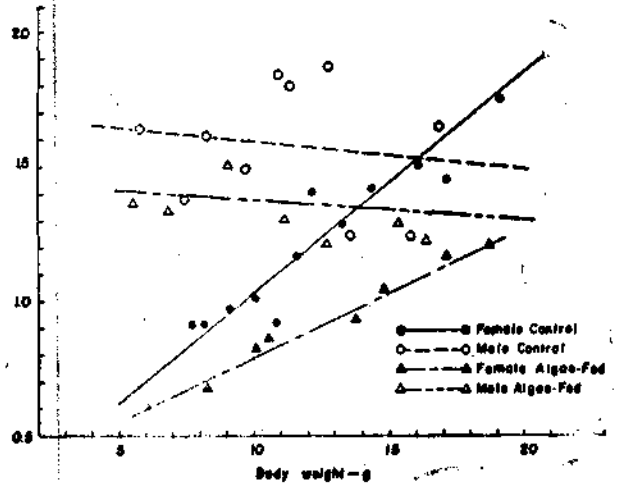

Fig. 4. Variations in the cholesterol content of the tail muscle of *P. aztecus* with reference to body weight. Regression equations : Male control y=1.6847−0.0094x, r=−0.146; Male algae fed y=1.4896−0.0148x, r=−0.6286; Female control y=0.2085+0.082x, r=0.9132 ; Female algae fed y=0.3113+0.0483x, r=0.9914. No significant differences between slopes of control and algae fed were found.

feeding and to the pelleted diet and the distribution of cholesterol with reference to sex and body weight in the blood, muscle, eyes and hepatopancreas. In general, the cholsterol content varied with body weight. Invariably the variation was an increase as the body weight increased. The increases were linear in the eyes (Fig. 5) and blood (Fig. 3) of males as well as in the hepatopancreas (Fig. 6), blood and muscle of females. The increase was curvilinear in the eyes of female shrimp (Fig. 5). The content was maintained at a steady level in the hepatopancreas (Fig. 6) and muscle (Fig. 4) of males, irrespective of body weight.

Compared to shrimp fed the pelleted diet, the algae-fed shrimp of both sexes showed significantly reduced levels of cholesterol in the tissues like muscle, hepatopancreas and blood (Figs. 3 to 6). Algae-feeding did not alter the levels in the eyes of either males or females (Fig. 5).

Discussion

Prawns (Kanazawa *et al.*, 1976) and crabs (Spaziani and Kater, 1973) showed tissue-specific variations in the cholesterol content. Species-specific variations were noticed in certain crabs by Zandee and Kruitwagen (1975) who reported that in *Cancer pagurus* the males showed a higher cholesterol level in the mid-gut gland than females. The present results ascertain the cholesterol levels in brown shrimp are not only tissue-specific but also sex-and size-specific as well as related to diet.

Lipid content of the whole shrimp was lower among females than males but the individual tissues of females showed significantly greater lipid contents than those of males (Table I and Fig. 1). This discrepancy may be due to dietary fats that were extracted when the whole shrimp was used for analyses. Or it might be due to 'depot lipids' which were not dealt with here. If the former view is held, there would be sex-specific variation in the absorption of dietary fats in shrimp.

The relative differences in lipid and cholesterol levels in tissues with reference to sex indicate the maintenance utilization of the store (Giese, 1966; Lawrence, 1976a). Female shrimp showed greater lipid levels as these animals supposedly require greater somatic lipid reserves for egg production in season. Blackmore (1969) demonstrated such mobilization and necessity of stores in limpets *Patella vulgata*. Aldrich (1974) has suggested that prepubescent moulting crabs such as *Libinia emarginata* have a higher usage of their hepatopancreas as shown by the higher proportional size and higher lipid level than mature non-moulting crabs. Probably the greater size and higher lipid level of the hepatopancreas of female shrimp (Fig. 2) may be a result of lipid storage in anticipation for gametogenetic activities. Lawrence (1976b) has shown that the hepatopancreas of two species of tropical hermit crabs, which are known to have seasonal reproduction, are large and store high levels of lipid preparatory to reproduction.

The cholesterol data obtained for *P. aztecus* in the present study are comparable with those of *P. japonicus* (Kanazawa *et al.*, 1976). In *P. japonicus* the eyestalks had the most cholesterol as well as the most lipid. In the present study with *P. aztecus* however, the eyes had the highest cholesterol content while the hepatopancreas had the most lipid. Optic ganglionic locations within the eyestalk of decapods differ greatly. The ganglion is located in the middle of the stalk in *P. aztecus* unlike the hermit crab where it is located at the base of the stalk (Gebe, 1966). The optic ganglion forms a major fraction of the stalk mass in shrimp. Nervous tissue is rich in cholesterol as the latter forms the structural component of all membrane (Kritchevsky, 1958). Probably for this reason, the eyes showed a high cholesterol level on a unit

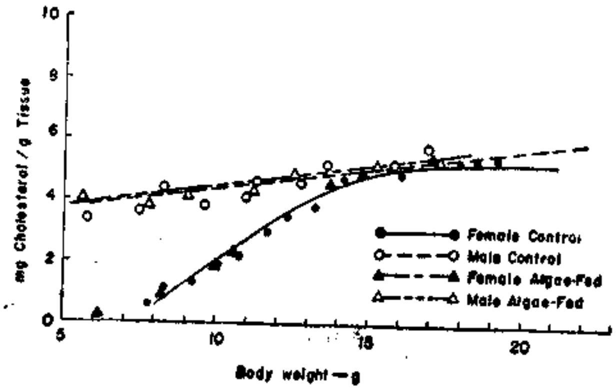

Fig. 5. Variations in the cholesterol content of the eyes of *Penaeus aztecus* with reference to body size. Regres sion equations: Male control $y=2.3618+0.1798x$, $r=0.8114$; Male algae fed $y=3.0274+0.1328x$, $r=0.9601$; Female control $y=-9.2637+1.5466x-0.0406x^2$, $r=0.9909$; Female algae fed $y=-9.281+1.54x-0.041x^2$, $r=0.9813$. No significant differences between slopes of control and algae fed were found.

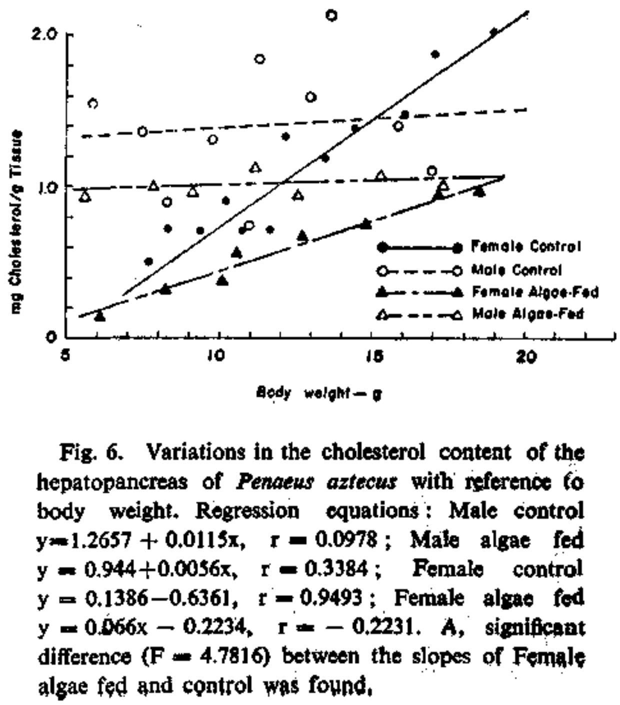

Fig. 6. Variations in the cholesterol content of the hepatopancreas of *Penaeus aztecus* with reference to body weight. Regression equations: Male control $y=1.2657+0.0115x$, $r=0.0978$; Male algae fed $y=0.944+0.0056x$, $r=0.3384$; Female control $y=0.1386-0.6361$, $r=0.9493$; Female algae fed $y=0.066x-0.2234$, $r=-0.2231$. A, significant difference ($F=4.7816$) between the slopes of Female algae fed and control was found.

weight basis. Algae-feeding did not alter the level in the eyes indicating the absence of 'depot' cholesterol.

Unlike vertebrates (Kritchevsky, 1958) the shrimp blood cholesterol increased with body weight. The reasons are yet unclear; perhaps greater mobilization or lesser peripheral utilization of cholesterol may keep the blood level increasing as the body weight increases.

The results presented here demonstrate that even in invertebrates such as shrimp, dietary factors influence the cholesterol levels in tissues. The factors present in the algal diet reduced the cholesterol levels significantly in the tissues such as muscle, and hepatopancreas; whereas starvation did not affect those levels. This is an interesting observation, worthy enough to pursue further in order to note the nature of the factors which are actually responsible for the low cholesterol content in shrimp. However, the experimental results demonstrated that maintenance of sufficient algae like *Ulva* and *Enteromorpha* in aquacultural systems, would lead to lessening the cholesterol accumulation or lowering of cholesterol reserves in the body.

The data on muscle cholesterol variations (Fig. 4) are particularly interesting because they give some information to evaluate objectively the reported cholesterol levels in shrimp as a human food. The majority of shrimp landed in the Gulf of Mexico are in the 60-68 heads-on count per lb size group (NOAA, 1974; Christmas and Etzold, 1977); each individual has a calculated mean whole body weight less than 7.9 g. The 68-heads-on count per lb is the legal minimum size in Mississippi to determine the opening of the shrimping season in the summer; this size constitute 70% of the catch. At this size according to the present results (Fig. 4) female *P. aztecus* have 0.776 mg cholesterol per g meat and males 1.6208 mg cholesterol per g meat. Unpublished data from this laboratory suggest that the sex ratio of brown shrimp in local inshore waters is 1 male to 3 females; offshore, the sex ratio varies from 1 male to 1.1 females upto 100 mm length and 1 male to 1.7 females above 100 mm length (Fisheries Assessment and Monitoring, 1978). The 1 male to 3 female catch ratio would give approximately 0.979 mg cholesterol per g meat, which is significantly lower than the cholesterol content of brains (20.0 mg/g), organ meats, (2.5 mg/g), caviar (3 mg/g), and eggs (300 mg/egg) (USDA, 1963; Feeley *et al.*, 1972; Scrimshaw, 1975). For offshore catches, the content varies from 1.089 to 1.184 mg/g. Similar extrapolation of data, assuming that shrimp are fed an algal diet *ad lib.* would give a content of 0.629 mg/g for the inshore catches while for offshore shrimp the level might vary from 0.945 to 1.017 mg/g. However, according to present results the smaller size of the shrimp, the lower the cholesterol level. The 'jumbo' shrimp available in the market would have a head-on weight around 14 to 15 g which, according to present computations, would show a cholesterol content close to the values reported in the literature (1.5 mg/g).

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RELATIVE ABUNDANCE AND DISTRIBUTION OF THE POSTLARVAE AND JUVENILES OF *PENAEUS MONODON* FABRICIUS IN THE COCHIN BACKWATERS AND THE PROSPECTS OF THEIR UTILIZATION IN CULTURE FISHERIES

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ABSTRACT

A survey of the seed resource of cultivable species of prawns conducted in the Cochin Backwaters at Puthuvypeen for a period of 13 months from May 1978 to May 1979 has revealed that the postlarvae of *Penaeus monodon* are available in fairly good numbers during April-May period. Using Midnapore type shooting net 419 post larvae were collected per hour in May 1978. In June and July their availability dropped markedly consequent to heavy monsoon. In June the catch per net per hour was 36 and in July it was 24. The catch per net per hour increased to 66 in August and then decreased to 12 in September. From October to December the post larvae of *P. monodon* were not present in the collection. In March 1979 they appeared again in sizeable quantities, the catch per net per hour being 189. They continued to be available and the catch improved to 232 per hour in April and 253 in May 1979. The percentage availability of *P. monodon* ranged between 3.7 in June 1978 and 0.17 in July 1978.

Juveniles of *P. monodon* were obtained in collections made with Midnapore type shooting net, drag net, hapa net and ring net, the maximum being with ring net operated underneath submerged marginal vegetation during September-October period. With drag net and hapa net the percentage availability of the juveniles was only 2.0 in September and 3.1 in October. The prospects of the utilization of the seed of *P. monodon* for culture in the brackishwater ponds and perennial prawn culture fields have been discussed.

INTRODUCTION

THE AVAILABILITY and distribution of the commercially important species of prawns along the southwest coast of India had been described by many earlier workers (George, 1962, 1968, 1973; Mohamed *et al.*, 1968; Rao, 1972, 1973). All these papers give information regarding the seasonal distribution of the larvae and post larvae of *Metapenaeus dobsoni* (Miers), *M. monoceros* (Fabricius), *M. affinis* (H. Milne Edwards), *Penaeus indicus* H. Milne Edwards and *Parapenaeopsis stylifera* (H. Milne Edwards). But information on the availability of the post larvae of *Penaeus monodon* in the west coast was lacking. The incursion of the postlarvae of *P. monodon* into the estuaries of the east coast has been noted by various authors (Rao, 1967; Subrahmanyam and Rao, 1968; Jhingran and Natarajan, 1972; Gopalakrishnan, 1973; Subramanyam and Ganapathi, 1975). The availability of *P. monodon* post larvae in appreciable quantities in the Cochin Backwaters has been recorded for the first time recently (Sebastian *et al.*, 1980).

In India, eventhough *P. monodon* is caught from both the east and west coasts, its contribution to the crustacean capture fishery is not very significant. *P. monodon* is caught from the estuaries and backwater systems as juveniles and subadults and as adults from the coastal and offshore beds. Its contribution to the

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prawn fisheries is more significant in the Coromondal coast (Jhingran, and Natarajan, 1972 and Gopalakrishnan, 1973). In Bengal it is now being utilized for culture in large scale. Owing to its many qualities such as fast growth, large size attained, and hardiness to withstand environmental stress, especially very low salinity, it is the most preferred variety of prawns for culture. As its culture gained importance, studies were also needed to assess the availability of its seed in the natural sources. It is with this in view that a survey of the seed availability had been conducted in the Cochin Backwaters. The present paper deals with the observations made during the survey near the Cochin bar mouth.

This study is a part of the work done under the All India Co-ordinated Research Project on Brackishwater Fish Farming sponsored by the Indian Council of Agricultural Research. The authors are grateful to Dr. V. G. Jhingran, former Project Co-ordinator and Director of Central Inland Fisheries Research Institute Barrackpore and Dr. A. V. Natarajan, present Project Co-ordinator and the Director of Central Inland Fisheries Research Institute, for their interest in the study and encouragement.

Material and Methods

The collection was made from Puthuvypeen, an area 2 km north of Cochin bar mouth, in a canal running parallel to the coast. The samples were collected mainly by using three different types of nets viz., Midnapore shooting net, hapa net and drag net, the first during the mid high tide and the latter two during the start of the high tide. The Midnapore shooting net is a funnel shaped conical net made of fine synthetic material, which is generally used for carp spawn collection in North Indian rivers. The main piece at its cod end has a stitched-in ring made of cane with a diameter of 30 cm. To this ring the 'gamcha' the tail piece is stitched in. Unlike as in the typical Midnapore net the 'gamcha' of the net used in this study is not open at its distal top. The 'gamcha' is conical in shape and is made up of handloom cloth material and is stitched at its broader side with the ring of the main piece. The tail end which has only 10 cm diameter is tied during operation. This net was operated against the current during the spring tide phase. The postl arvae of the prawns are collected at the tail end. The collection is removed periodically in order to avoid too many crabs concentrating at the tail end and destroying the net.

The hapa net used in this study is made of velon net material having a size of 2 × 1 × 1 m. This was operated by two men. Two sticks tied at the two sides helped to keep the net open and also to hold the net by the two operators while operating in shallow water for collecting the prawn juveniles. The drag net used is made up of synthetic material with a mesh size of 15 mm. It has a dimension of 7 × 4 × 1 m. The mouth end remains open when operated as sticks of 1 m height are provided at 1 metre intervals. Ring nets having a diameter of 80 cm at the mouth and a depth of 80 cm are used for collection of the juveniles of *P. monodon* which have a tendency to remain under submerged marginal vegetation.

Observations

The availability of the post larvae and the juveniles of *P. monodon* in a period of 13 months, starting from May 1978, collected using Midnapore net in respect of the post larvae and with hapa net and drag net in the case of juveniles are shown in Figs. 1 and 2 respectively. The maximum number of post larvae obtained worked out to 419 per net per hour during the month of May 1978. The percentage of *P. monodon* in the total collection was only 3.5 (Table 1). Consequent to the start of the monsoon there was a sudden drop in the availlability of the postlarvae of all prawns. The catch per net per hour for *P. monodon* postlarvae dropped to 36 numbers. The percentage remained more or less the same. In July 1978, the availability of the total number of postlarvae increased but that of *P. monodon* dropped further accounting only 24 per net per hour. It constituted only 0.17% of the total. In August there was a slight increase in the availability, the number collected per hour being 66 which is 1.3% of total number of prawn postlarvae. In September there was again a decrease, the total number collected per hour dropping to 12, which is only 1.07% of the total. During the months of October, November and December, *P. monodon* postlarvae were not encountered in Midnapore net collections made in the area, although the other species of prawns such as *P. indicus*, *M. monoceros* and *M. dobsoni* were available in appreciable numbers. From January 1979 onwards they started appearing in limited numbers. In January, 26 postlarvae of *P. monodon* were obtained which account for 3.6% of the total number of postlarvae of cultivable species of prawns obtained with Midnapore shooting net. In February 1979, 31 postlarvae were obtained constituting 2.7% of the total number. From March onwards the availability increased, the number of postlarvae obtained had gone up to 189 (3.3%) and in April it was 232 (2.3%). In May 1979 the number had gone upto 253 which is 3.2% of the total.

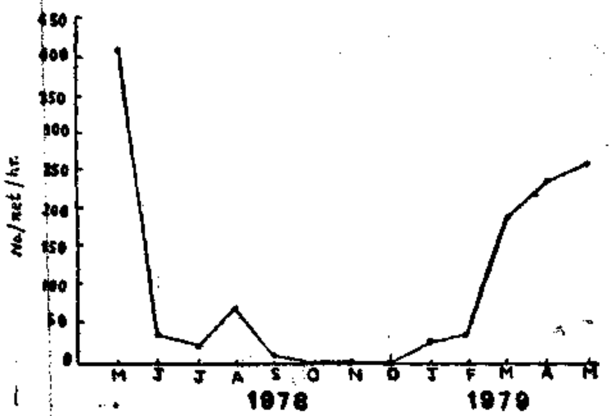

Fig. 1. Monthly distribution of postlarvae of *Penaeus monodon* in the Cochin Backwaters during 1978-79.

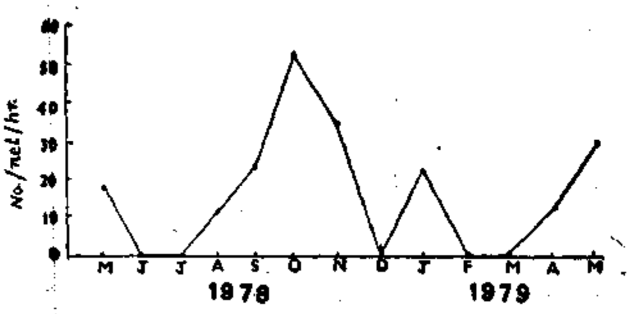

Fig. 2. Monthly distribution of juveniles of *Penaeus monodon* in the Cochin Backwaters during 1978-79.

The study of the percentage availability of different penaeid postlarvae during the period had revealed that the availability of *P. indicus* is as high as 66.75% in December '78, whereas *M. dobsoni* accounted for 18.75%, *M. monoceros* 10.5% and *M. affinis* 4%. During this month no *P. monodon* postlarvae were present in the collection. Contrary to this, in June when *P. monodon* postlarvae went upto 3.7%, the percentage of *P. indicus* was 15.0, that of *M. dobsoni* 50, *M. monoceros* 27.5 and *M. affinis* 3.8 respectively. From the present study, it is seen that the percentage availability of *M. dobsoni* is fairly high throughout, the lowest being 18.75 during December 1978 when the availability of *P. indicus* was maximum. The highest percentage of 66.6 *M. dobsoni* was obtained in July 1978. The availability of *M. monoceros* and *M. affinis* remained very low, being of the order of 6.6–27.5% in the case of former and 1.5–9.02% in the case of the latter.

The juveniles of *P. monodon* were obtained in collections made with Midnapore shooting net, drag net, hapa net and ring net. The maximum number were obtained with

TABLE 1. *Percentage Availability of the postlarvae and juveniles of various penaeid prawns from the Cochin Backwaters during the year 1978-1979*

	Months												
	1978										1979		
Species	May	June	July	August	Sept.	Oct.	Nov.	Dec.	January	Feb.	March	April	May
						Postlarvae							
P. indicus	25.0	15.0	11.20	8.0	30.82	28.50	53.70	66.75	30.30	35.0	33.3	52.0	42.34
P. monodon	3.5	3.7	0.17	1.3	1.01	—	—	—	3.60	2.7	3.3	2.3	3.20
M. dobsoni	38.5	50.0	66.60	68.0	42.49	55.60	24.07	18.75	46.10	46.1	53.3	36.0	44.50
M. monoceros	27.5	27.5	22.03	21.2	16.66	14.30	20.70	10.50	15.70	11.9	6.6	8.0	7.50
M. affinis	5.5	3.8	—	1.5	9.02	1.60	1.53	4.00	4.30	4.30	3.5	1.7	2.46
						Juveniles							
P. indicus	53.2	17.6	22.4	4.5	36.2	132.4	31.0	72.0	57.3	24.70	38.8	49.5	40.4
P. monodon	2.5	—	—	1.1	2.0	3.10	2.0	—	1.3	—	—	0.6	2.9
M. dobsoni	26.4	77.3	71.2	59.2	54.1	52.63	45.0	18.0	30.6	54.40	45.8	31.6	37.0
M. monoceros	15.4	4.2	4.7	31.5	4.8	29.56	16.0	6.0	6.6	16.84	10.7	16.7	15.0
M. affinis	2.5	0.9	1.7	3.7	2.9	1.47	6.0	4.0	4.2	4.06	4.7	1.6	4.7

ring net operated underneath marginal vegetation during October 1978, when 54 juveniles of *P. monodon* were obtained per net per hour. This constituted 3.1% of the total collected. The availability of juveniles in the collection started in August and continued upto November with the peak in October (Fig. 2). In December '78, the juveniles were not available, and only few could be collected in January 1979. The juveniles were not encountered in the collections made during February and March 1979. In April they started appearing and were collected in limited numbers. The catch per net per hour worked to 12 and 30 for April and May 1979. The availability of the juveniles of other penaeid prawns was maximum during the pre-monsoon season. *P. indicus* contributed to the maximum of 72.0% in December 1978. The minimum of 4.5% was recorded in August 1978. The range of percentage availability of *M. dobsoni* was between 18.0% in December and 77.3% in June '78. In the case of *M. monoceros*, the percentage availability ranged between 4.2% and 29.56%, the minimum during June and the maximum during October '78. *M. affinis* was available only in very limited numbers. Its contribution was as low as 0.9% in June '78 and the maximum availability of 6.0% was in November '78.

Discussion

The availability of the postlarvae of *P. monodon* in the Cochin Backwaters in appreciable numbers, which can be exploited commercially for culture operations has been established by the present study. Eventhough the percentage availability of *P. monodon* is very low, being around 3%, the number that could be collected per net per tide is as high as 1200. The earlier workers (George, 1962; Rao, 1972; Kuttyamma, 1975) who studied the availability and the seasonal abundance of the postlarvae of commercially important prawns in the Cochin Backwaters have not mentioned such availability of the postlarvae of *P. monodon*. The general pattern of the seasonal distribution and percentage availability of the other species of prawns *viz. P. indicus, M. dobsoni, M. monoceros* and *M. affinis* as observed in the present study is in agreement with the observation of Rao (1972).

Two peaks were observed in the incursion of the postlarvae of *P. monodon*, one during November-January, and the other during April-June period, in the east coast by Subramaniam and Ganapati (1971), but only one such peak, the latter occurring during the April-June period could be observed in the present study. The peak availability of postlarvae was noticed in the April-May period, whereas that of the juveniles was observed in September-October period. The percentage availability of both the postlarvae and the juveniles remained more or less the same, around 3%, in the peak availability periods. Owing to the capacity to tolerate low saline conditions in the case of *P. monodon* and to the preference for higher salinities in the case of *P. indicus*, the percentage availability of *P. monodon* juveniles could have been more than what is available now in the backwaters during the monsoon months. The turbidity of the water and the silting of the beds of the backwaters during the rainy season could be adversely affecting the survival of the postlarvae recruited just prior to the start of the southwest monsoon.

The present study has indicated that by using special type of device like the Midnapore shooting net, the postlarvae of *P. monodon* having a size of 12-15 mm could be collected in appreciable numbers. *P. monodon* is the most important prawn from the culture point of view, as it has got the fastest rate of growth, high tolerance to environmental variations and better market preference. The postlarvae of this prawn available in the Cochin Backwaters just prior to and during the monsoon season can be utilized for culture in brackishwater ponds and the perennial prawn culture fields. The postlarvae could be reared in nurseries prepared after eradicating the weed and predatory fishes by the application of Mahua oil cake at a dose of 200 ppm and manuring with 100 kg/ha urea and 200 kg/ha rock phosphate. In the nurseries they can be reared for a period of one month at a density of 1 lakh per hectare. Within this period they will grow to a size of 25-40 mm. These could be stocked in the perennial prawn culture fields and brackishwater ponds alone at a concentration of 25,000/ha or along with fishes like *Etroplus suratensis*, *Mugil cephalus* and *Chanos chanos*. It is during this period that the seed of these fishes are available at their maximum abundance in the Cochin Backwaters. The finding of the availability of the seed of *P. monodon* is significant in the context of the fact that other cultivable species of prawns viz. *P. indicus* cannot be grown in the perennial prawn fields during the monsoon months owing to its requirement of higher salinity. The salinity during this period will be less than 2‰ in most of these fields. The juveniles available during the monsoon period can also be collected and profitably cultured in the brackishwater ponds and perennial prawn culture fields during the rainy season.

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STUDIES ON THE POSSIBILITY OF INTENSIVE CULTURE OF PRAWNS

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ABSTRACT

The present study was carried out to determine the growth rate and production of the white prawn *Penaeus indicus* at very high stocking rates in sea-water tanks with continuous aeration. The prawn were stocked at a rate of 2000 postlarvae per sq. m for nursery rearing and 100 juveniles per sq. m for grow-out. The paper describes about the observations made on growth, feed, survival rate and problems in rearing. The results appear to indicate promising possibilities and potentials for establishing new prawn culture industry, apart from brackishwater farming.

INTRODUCTION

CULTURE of penaeid prawns in brackish water ponds have gained much importance in the recent years, at it has a very high potential for aquaculture. It has been observed that due to the presence of large numbers of predatory fish which feed heavily on prawns, the production in brackishwater ponds is always much lower, than their actual productive potential (Ling, 1968). Research investigations from several brackishwater farms have shown that it is possible to obtain an yield of 1 to 1.5 tons per hectare per year in two crops (Sundararajan, *et al*., 1980, Blanco, 1972, Djajadiredja and Purnomo, 1972). The stocking density ranges from 30 to 50 postlarvae per sq. m for nursery ponds and 3 to 5 juveniles per sq. m for grow-out ponds, in brackishwater prawn farming.

Experiments on intensive culture conducted by Shigueno (1975) in Japan reveals the possibility of harvesting a crop at a rate of 2.2 kg/sq. m. In such experimental pilot farms the stocking density was as high as 123 per sq. m the period of rearing being 6 months. Intensive culture of shrimps in closed raceways with a stocking rate of 150 per sq. m yielded a production of 0.7 kg/sq. m (Mock, 1973). Intensive culture of penaeid shrimps in controlled environment has been described by Mock *et al*. (1973). They reared postlarvae at densities of 2300 sq. m with survival rates of 90 to 95 per cent. Juveniles have been reared at densities of 100 sq. m to 1600 sq. m with survival rates ranging from 80 to 97 per cent.

In the present study experiments were carried out at a stocking rate of 200 postlarvae/sq. m for nursery rearing and 100 juveniles/sq. m for grow-out rearing to observe the productive potential in intensive rearing.

MATERIAL AND METHODS

Penaeus indicus postlarvae were collected from the Adyar estuary and were reared in 0.5 sq. m tanks. Provisions were made for continuous aeration with diffuser stones. Seawater was changed daily. A sand layer was provided in the tanks.

RESULTS

Nursery rearing

1000 postlarvae of *P. indicus* were stocked in a tank of 0.5 sq. m at a rate of

2,000 postlarvae per sq. m. The length (tip of rostrum to tip of telson) at the commencement of rearing ranged from 10 to 15 mm. After 30 days of rearing 80 per cent of the population was harvested. The length of the prawns ranged from 40 to 60 mm with an average of 47.6 mm. The average increment in growth in 30 days of rearing was 33.6 mm.

The postlarvae were fed with Chironemid larvae for the first fortnight and subsequently with fresh *Acetes* boiled and minced fish flesh, boiled and minced clam, and dried *Acetes*. In the earlier experiments attempts were made to feed the prawns with crushed meat, but it was found that the fat content pollutes the water and causes mortality and that raw beet or meat is not much preferred as compared of other feeds mentioned above. Insufficient feeding leads to cannibalism. The unconsumed feed was not allowed to decay and was removed after four to five hours of feeding.

The sand layer turns black in colour and emits foul odour due to the formation of abnoxious gases and to check this, the provision of false bottom as described by Shigueno (1973) was considered. Siddharaju *et al*. (1980) have reared prawns in off bottom cages and have observed good growth.

Rearing of juveniles

Fifty *P. indicus* juveniles were stocked in a tank of 0.5 sq. m area. The size at the time of stocking ranged from 40 to 50 mm with an average length of 42.5 mm.

For the first 30 days of rearing, the prawns were fed with boiled fish flesh and clam meat at the rate of 10% of prawn body weight daily. After 30 days of rearing the length ranged from 45 to 70 mm with an average length of 60.6 mm. The increment in growth was 18.1 mm.

After 60 days of rearing, in spite of giving the same type of food, the length ranged from 50 to 85 mm with an average length of 68 mm. The increment in growth was only 7.4 mm for the second 30 days.

After 90 days of rearing the size ranged from 55 to 90 mm, and the average length was 76.2 mm. The increment in growth was 8.2 mm for the third month. Since it was felt that the growth rate was not faster, a formula feed was prepared with squid meal and *Acetes* meal as the main ingredients and was fed at the rate of 10% of the body weight.

On the 110th day, the prawns were harvested. The length ranged from 65 to 100 mm with an average length of 81.4 mm. The weight of individuals ranged from 3 to 8 g with an average weight of 6 g. The increment in growth from stocking to harvest was 38.9 mm. The total yield from 0.5 sq. m tank was 200 g which worked out to 400 g/sq. m. Survival was 70 per cent.

In the above experiments water quality was periodically checked. The pH was around 8.4. Salinity averaged 34 ppt and oxygen level was always kept high by continuous aeration.

Discussion

Mock (1973) has reported experiments on the intensive culture of penaeid shrimp *P. setiferus* at a stocking density of 2370 sq. m. The average length at stocking was 5.7 mm. After 22 days of rearing the average length obtained was 22.4 mm. The survival rate was 94%. The results of the present study with a net growth of 33.6 mm in 30 days compare well with that of Mock (1973).

Mock (1973) experimented on stocking of juvenile shrimps at 156 sq. m for a duration of 63 days. 97% was harvested. The shrimps averaged 86.6 mm in length and 4.6 g in weight with a production of 0.7 kg/sq. m. The production of 0.4 kg/sq. m obtained in the present study is comparatively low.

Alikunhi *et al.* (1980) conducted experiments to investigate the possibilities of rearing advanced postlarval stages in intensive systems without artificial aeration, but with partial renewal of water and regular artificial feeding *P. merguiensis* was stocked at a rate of 1000, 2000, 3000, 4000 advanced postlarvae per sq. m and the percentage of survival was 96, 75, 78 and 55 respectively.

P. monodon was stocked at a rate of 1000 and 1500 per sq. m. Average percentage of survival was 73 and 59. In the present study, the results on survival at comparable stocking density are more or less the same.

Experiments on intensive culture of *P. japonicus* were conducted in farms in Japan. In rectangulr tanks *P. japonicus* were stocked at a rate of an 123/sq. m. After six months of rearing 91% of the population was harvested with an yield of 2.266 kg/sq. m (Shiguero, 1975).

The results of the present study compare favourably with those obtained in brackish-water pond culture of *P. indicus* at Santhome, Madras. In ponds which were stocked at 4 lakhs/hectare with 14 mm postlarvae, they attained an average length of 41.5 mm in 30 days, showing a growth of 37.5 mm. In grow-out ponds juveniles stocked at 70,000 hectare showed a growth of 99.4 mm in length and 7.3 g in weight in 90 days.

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EXPERIMENTS ON THE TRANSPORT OF POSTLARVAE OF TIGER PRAWN *PENAEUS MONODON* FABRICIUS

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ABSTRACT

For intensive prawn farming, selective stocking of seed in large numbers is an essential prerequisite. *Penaeus monodon* postlarvae of 11-14 mm size collected from nature were conditioned for 24 hours in earthen pits and packed in knotless polythene bags (18 litre capacity) with oxygen in different water salinities at the rate of 375 no/l of water. Encouraging results were obtained when the postlarvae of *P. monodon* were put in 8‰ water salinity at the rate of 375 no/l for a duration of 26 hours. Chloral hydrate was used as a sedative for the transport of tiger prawn. A dose of 400 mg/l was found to be the most effective dose for successful transportation of 375 no/l upto a period of 28 hours. The range of temperature between 29°C and 30°C was found to be the optimum. Details of the observation have been dealt with in the paper.

INTRODUCTION

IN RECENT YEARS there is great demand of quality prawns and shrimps because of their high price in foreign markets and this has attracted a good number of farmers for large scale shrimp farming. The shrimp trade mainly depends on the marine catches and there is no exclusive shrimp farming on commercial scale in this country, although brackishwater fish farming has been carried out for long based on the empirical knowledge of fishermen. The traditional practice had been stocking of mud-enclosures constructed in the intertidal zone of the estuaries of lower Sunderbans and the bank of the backwaters of Kerala. With each tidal inflow, particularly during the lunar phase, innumerable prawn and fish species find entry into these enclosures commonly known as *Bheries* in West Bengal.

It is necessary to stock the seed of economic prawn species exclusively by transplanting them from the lotic environment to lentic brackishwater impoundments (*bheries*) for culture. For this purpose, the postlarvae of cultivated species of prawns and shrimps has to be collected with the help of special type of gears, then segregated and acclimatised in specially made hapas before transporting to the places where these are to be transplanted. For this purpose experiments were conducted on the transport of postlarve of tiger prawn *Penaeus monodon* and the results are presented in the ensuing section.

The authors are grateful to Dr. A. V. Natarajan, Director of the Institute for providing all facilities to conduct the experiments.

MATERIAL AND METHODS

P. monodon postlarvae (11-14 mm) were collected by operating modified shooting nets generally used for catching carp fry at Taldi near Port Canning in February to June. Nets were operated during full and new moon phases.

The postlarvae collected in 'gamcha' (tail piece) were periodically removed and transferred to round plastic tubs of 50 litre capacity. *P. monodon* postlarvae were identified by the presence of a distinct pigmented ventral margin (red streak). Their habit of clinging to the floating objects was taken advantage of for the purpose of segregation. Aquatic grass shoots, hay, etc. were bundled and put into plastic tubs containing the larvae. *P. monodon* postlarvae have a tendency to be attached to the bundles when immersed in water containing the seed. The postlarvae were conditioned for 24 hours in earthen pits dug out on the bank where the creek water was mixed with fresh pond water (50 : 50) to maintain the salinity at 8 ppt. They were then packed in knotless polythene bags of 18 litre capacity and oxygen was added from the cylinder. The dose of chloral hydrate was adjusted by carrying out experiments in the laboratory. Physico-chemical parameters during the course of transportation experiments are given in Table 1.

RESULTS

The experiments were conducted in polythene bags with and without anaesthesia under oxygen at the rate of 250 no/l, 375 no/l, and 500 no/l. The oxygenated polythene bags containing *P. monodon* postlarvae were transported from Taldi to Calcutta for observations in the laboratory. The three sets of transported specimens mentioned above started dying after 24 hours, 18 hours and 12 hours respectively. In case of control, the mortality of postlarvae started after 30 minutes and all died within 1½ hours. The percentage of survival was 97.8, 95.4 and 97.9 with packing densities of 250/l, 375/l and 500/l during 24, 18 and 12 hours respectively. The maximum and minimum survival rates of 91.1 and 50% were observed in packing densities of 250/l and 500/l respectively without anaesthesia. In case of anaesthetised specimens, the highest survival (98.7%) was observed at the packing density of 250/l during 24 hours duration. Four replications were made with one control in each set of experiments.

Chloral hydrate was used as a sedative for raising the survival rate of prawn postlarvae under oxygen packing. To begin with a test dose of 400 mg/l was tried for anaesthesing *P. monodon* postlarvae. The sedative helped in raising the survival rate from 0.9 to 15.6%.

TABLE 1. *Physico-chemical parameters recorded during the transportation experiments of P. monodon* postlarvae

	Packing Density					
	250/l		375/l		500/l	
	Initial	Final	Initial	Final	Initial	Final
pH	8.0	7.8	8.0	7.4	8.0	7.1
CO_2 (ppm)	Nil	6.0	Nil	36.0	Nil	54.0
O_2 (ppm)	7.7	6.2	7.7	2.7	7.7	3.0
Water temp. (°C)	28.5	31.0	28.5	31.0	28.5	31.0
Air temp. (°C)	31.0	36.0	31.0	36.0	31.0	36.0
Water salinity (‰)	8		8		8	

The maximum difference of 15.6% in the anaesthetised postlarvae was during 30 hours of observation of 2,500 postlarvae at a packing density of 500/l. Results of a collational study of the survival rate with and without anaesthesia has been shown in Fig. 1.

started dying after half an hour and the whole lot perished within a spell of 1-2 hours depending upon the density and temperature. Mohanty and Patra (1972) recommended a packing density of 100 postlarvae per container for 9 hours. De and Subrahmanyam

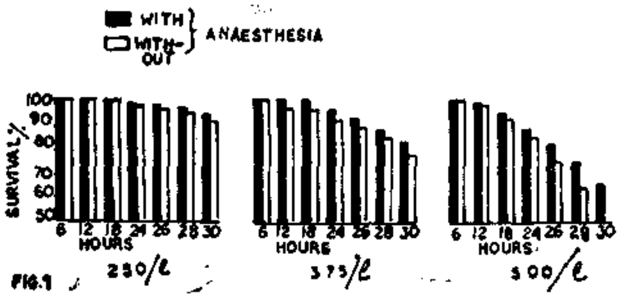

Fig. 1. A collational study of the survival rate with and without anaesthesia.

While carrying out these expriments, it was observed that the design of the polythene bag/container especially the base line has a role as regards their survival rate. It was noticed that the bags with folds or knots at the bottom (which are used for the transportation of the carp seed) were not suitable for transporting prawn seed. Soon after packing, about 5% of the postlarvae got entangled within the folds and died. This started fouling the water. Thus a poor survival rate of 30 to 60% was obeserved in such bags having folds or knots at the bottom, mainly due to the fact that initial mortality made the media uncongenial for their survival. Instead, the survival rate in the knotless polythene bags ranged between 50 to 90% under similar conditions.

Discussion

The problem of transportation of penaeid prawn postlarvae is well known. The experiment was initially conducted in a 5 litre open container and it was found that the specimens

(1975) recommended the packing density of 500/l for 36 hours duration. The results of the present studies of the experiments however, did not tally with either of the aforesaid workers.

During the experiments with the packing densities of 250/l, negligible mortality was observed till 18 hours durtion after which the postlarvae started dying and all of them died after 48 hours of packing both in case of anaesthetised and non-anaesthetised specimens. Compared to this, in the bags packed at the rate of 375/l, there was no mortality till 12 hours while there was 100% mortality after 44 hours in case of chloral hydrate treated and 41 hours of the untreated specimens. In the third lot packed at the rate of 500/l. mortality started after 10 hours of packing and all the specimens died after 37 hours.

Taking into account the results of the experiments with different packing densities and their corresponding survival rates, it may be assumed that a packing density of 500/l is the optimum rate for tansportation of anaesthetised of *P. monodon* postlarvae for a period not exceeding 26 hours. Whereas a packing density of 375/1 can be recommended for 27-30 hours period of transit. Beyond 30 hours, mortality increases at geometrical progression. However, in certain unavoidable cases of transportation involving a journey exceeding 30 hours, certain additional steps such as repacking during transit has to be done.

In order to determine the role of chloral hydrate, a common anaesthesia used in fish transportation was used on some specimens. A mild sedation was observed soon after the treatment, but the postlarvae recovered to normal condition immediately after their release in untreated water. In case of higher packing density (500/1) the difference of survival rate was conspicuous (15.6%) while at lower packing densities (250/1) it was not so (0.9%). The experiments led to the conclusion that sedation was helpful in higher packing densities than in lower ones.

Another interesting observation is about the survival of prawn larvae in knotted and knotless bags during transport. The folds at the bottom of the folded or knotted polythene bags generally entangle the tiny, slender postlarvae in large numbers as observed earlier by De and Subrahmanyam. However, experiments are in progress to find the remedial measure. In a separate experiment, it was found that the initial mortality after packing is mainly responsible for subsequent higher mortalities.

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EFFECT OF SALINITY ON GROWTH AND SURVIVAL OF THREE SPECIES OF PENAEID PRAWNS

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ABSTRACT

Laboratory experiments were conducted to elucidate the effect of different salinity levels (5‰, 15‰, 25‰, 35‰, 45‰) on the growth and survival of *Penaeus indicus*, *P. monodon* and *P. semisulcatus*. Postlarvae collected from the Pulicat Lake were acclimated to the respective test salinity levels gradually from the brackishwater from which they were collected and the experiments were conducted for a period of 60 days. In *P. indicus* highest mean weight gain (37 mg/day) was attained at 25‰ level followed by 15‰, and 5‰ levels of salinity and the lowest weight gain (4 mg/day) was attained at 45‰ salinity level. Survival rates were also high in low salinity levels of 5‰, 15‰ and 25‰ compared to that of high salinity levels of 35‰ and 45‰. *P. monodon* showed the highest mean weight gain (48 mg/day) at 25‰ level followed by 15‰ and 5‰ levels, and growth was comparatively poor at 45‰, and 35‰ salinity levels. However, high survival rates (86% to 100%) were obtained for this species at all tested salinity levels. Among the three species studied, *P. semisulcatus* showed poor growth and survival at the low saline level of 5‰ and at hypersaline level of 45‰. This species showed better growth and survival rates at salinity levels of 15‰ and 25‰.

The results of the experiments clearly indicate the variaton existing among the three species with reference to their preference for salinity. *P. monodon* showed better growth and survival rates at all salinity levels compared to *P. indicus* and *P. semisulcatus*. However, both *P. monodon* and *P. indicus* seem to show a preference for low salinity levels ranging from 5‰ to 25‰. The lowest mean weight gain attained at 45‰ for all the three species indicates the unsuitability of hypersaline water bodies in the life of penaeid young ones.

INTRODUCTION

THE SEMI-CATADROMOUS, cyclic life of most of the penaeids involving the sea and low-saline coastal ecosystems has been well established now and salinity has been considered as one of the important abiotic factors influencing the survival, growth and distribution of tropical penaeids, especially during their life in nursery grounds, where they are exposed to the marked changes in the salinity of the environment. A prior knowledge of the effects of salinity on the food-intake, food conversion efficiency, growth and survival is very important in prawn culture operations, since salinity, along with other abiotic and biotic factors determine the survival, growth and thereby the production of prawns. A number of reports exist on the effect of different salinity levels on the growth and survival of penaeid postlarvae and juveniles (Williams, 1960; Zein-Eldin, 1963; Zein-Eldin and Griffith, 1969; Grajcer and Neal, 1972; Venkataramiah *et al.*, 1972) and many others exist on the cumulative effect of temperature and salinity on the growth and survival, food intake and food conversion efficiency (Zein-Eldin and Aldrich, 1965; Venkataramiah

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et al., 1973, 1974, 1975). However, despite the availability of extensive studies on the biology of Indian penaeids, aside from the work of Nair and Krishnankutty (1975) on *P. indicus*, there is no report on the effect of different salinity levels on the growth and survival of other Indian penaeids. The objective of the present study was to elucidate the effect of different salinity levels on the growth and survival of *Penaeus indicus*. *P. monodon* and *P. semisulcatus* based on laboratory experiments.

The authors wish to express their gratitude to the Principal, Madras Christian College for providing facilities at the Estuarine Biological Laboratory at Pulicat to carry out this study. One of them (R.P.R.) gratefully acknowledges the award of a Junior Research Fellowship by the Council of Scientific and Industrial Research, New Delhi.

Material and Methods

Postlarvae and juveniles of all the three species of experimented prawns were encountered from a wide range of salinities from their nursery grounds of Pulicat Lake (Raj, 1976), and therefore, salinity levels of 5‰, 15‰, 25‰, 35‰ and 45‰ were used in the present experiments. Postlarvae collected from the Pulicat Lake using a 'Velon Net' were transported to the laboratory in plastic buckets in the same brackishwater medium from which they were caught. In the laboratory they were identified, segregated and the different species were kept in aquarium tanks. The salinity, temperature and oxygen content of the site of collection were 27.5‰, 26.5°C and 7 ml/l, respectively.

Acclimatization

The desired salinity level in each tank was obtained by the addition of hypersaline lagoon water (56‰) mixed with sea water (33‰) for higher salinity levels (35‰ and 45‰) and by the addition of dechlorinated tap water for low salinity levels (5‰ to 25‰). The desired salinity levels were obtained in 6 days and the total period of acclimation was eight days at all salinity levels.

Experimental procedure

Plastic aquarium tanks of sizes 60 × 30 × 30 cm were used for rearing the postlarvae. Sieved, clean beach sand was used as a substrate (3 cm depth) in the tanks. Among the acclimated postlarvae, only 50 postlarvae were reared at each salinity level in the plastic aquaria for 15 days and were then transferred to cement tanks (size 75 cm diameter × 52 cm depth), with sand as substrate, during further period of rearing. Same salinity levels were maintained in the concerned tanks. All the experimental containers were aerated well with aerators and the experimental medium was partly changed once a week with a fresh medium of the same salinity level. Temperatures in the aquarium tanks ranged from 26 to 29.5°C during the experimental period of 60 days from the time of acclimation to the respective test salinity levels. The same procedure of acclimation and rearing was adopted for all the three species, and the experiments were conducted simultaneously to make a comparative assessment of the effect of salinity on growth and survival of the three species of penaeids.

Food and feeding

Feeding of the prawns were done with a pelleted feed, the composition of which is given in Table 1. The individual food components were dried and powdered, except tapioca, which was cooked, dried and powdered. Fine wheat flour (about 5 g per 200 g of feed) was boiled in water and made into a paste and the food ingredients were mixed thoroughly with water and then passed through a household pelletiser, dried and stored for experimental purposes. Food was supplied in excess through out the experimental period and the feeding was done once in the evening hours daily and the left-over food was removed from the feeding trays in the following morning.

TABLE 1. *Ingredients used for preparation of pellet feed (by dry weight)*

Ingredient	Percentage
Prawn heads	50
Clam meat (*Meretix casta*)	5
Trash fish	5
Rice bran	10
Tapioca	20
Algae	10

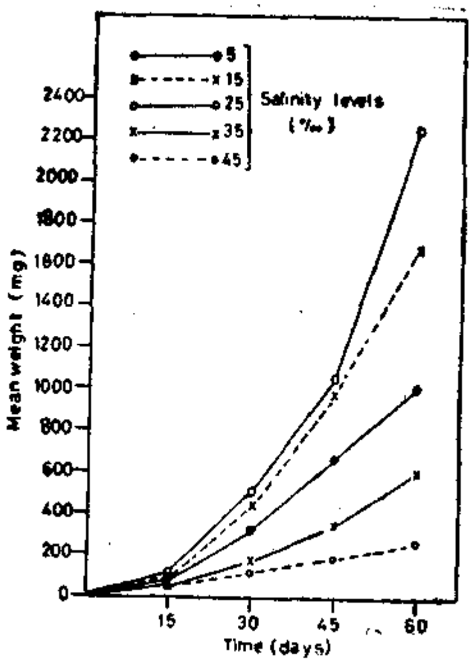

Fig. 1. Growth (mean weight increase) of *P. indicus* at indicated salinity levels.

Sampling procedure

The initial weights and total lengths of ten postlarvae from each tank were taken after the acclimation period, and, thereafter, sampling was done once a fortnight and the prawns were returned to the tanks after taking their total weights and individual total lengths. At the end of the experiment, the total number of surviving prawns were counted from each tank, their individual total lengths and weights were taken and the mean growth per day was calculated.

RESULTS

Penaeus indicus

The mean weight and length increases of *P. indicus* during the experimental period at different salinity levels are shown in Figs. 1 and 2. Growth of the postlarvae occurred at all the salinity levels tested, and the weight increase (Fig. 1) was more rapid than the total length increase (Fig. 2). Among the five

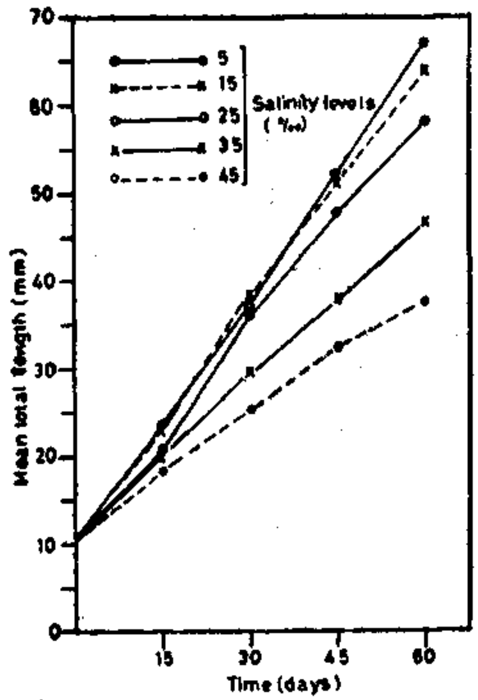

Fig. 2. Growth (mean length increase) of *P. indicus* at indicated salinity levels.

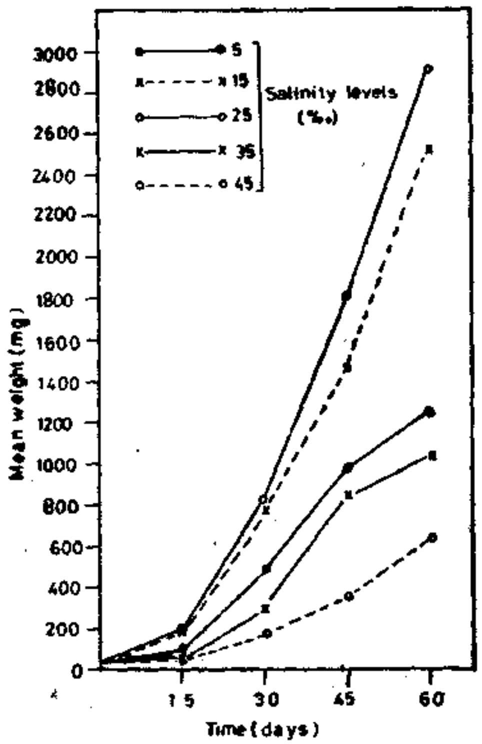

Fig. 3. Growth (mean weight increase) of *P. monodon* at indicated salinity levels.

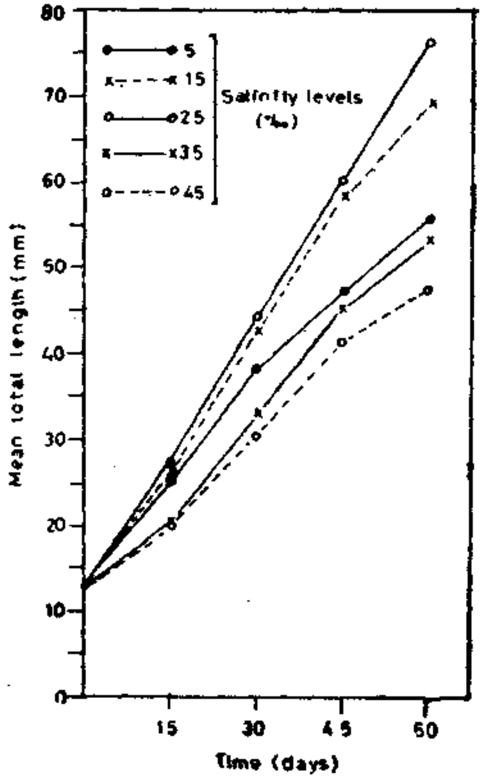

Fig. 4. Growth (mean length increase) of *P. monodon* at indicated salinity levels.

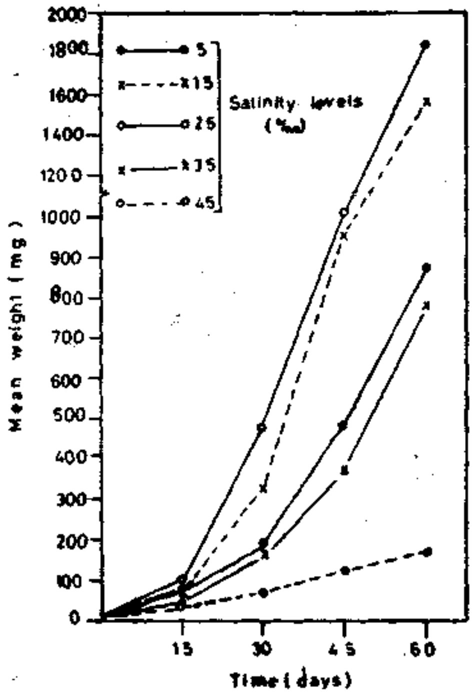

Fig. 5. Growth (mean weight increase) of *P. semisulcatus* at indicated salinity levels.

salinity levels tested for this species, growth was better at the low salinity levels of 5‰, 15‰ and 25‰ than at the high salinity levels of 35‰ and 45‰. Moreover, growth was much greater at 25‰ salinity level compared to all other salinity levels ; and the mean weight

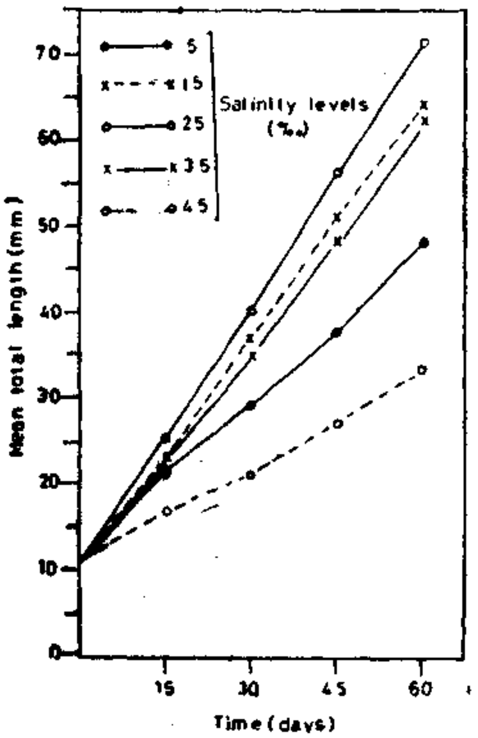

Fig. 6. Growth (mean length increase) of *P. semisulcatus* at indicated salinity levels.

gain of 37 mg per day (Fig. 7) recorded at 25‰ is about nine times higher than that (4 mg per day) recorded at a high salinity level of 45‰. Even among the three low salinity levels tested, there was significantly higher growth rates at 15‰ (27 mg and 0.88 mm/day) and 25‰ (37 mg and 0.93 mm/day) salinity levels compared to 5‰ (16.5 mg and 0.78mm/day) level.

The per cent survival (Fig. 8) was also much higher at low salinity levels than at high salinity levels. Survival rates ranged from 92 to 96‰ in low salinity levels, and 70 to 72% for high salinity levels.

Penaeus monodon

The growth of *P. monodon* at different salinity levels is represented in Figs. 3 and 4. As in the case of *P. indicus*, growth in terms of weight increase (Fig. 3) was more marked than growth in terms of length increase (Fig. 4). Growth in this species was also higher in low salinity levels than at high salinity levels. Growth curve for this species (Fig. 7) showed that the highest mean weight gain of 48 mg per day attained at 25‰, level was much higher than that (10 mg per day) recorded at a salinity level of 45‰. Even for this species the optimum salinity range for better growth and survival appeared to be within the range of 15 to 25‰, since best growth rates (Fig. 7) were attained at these levels.

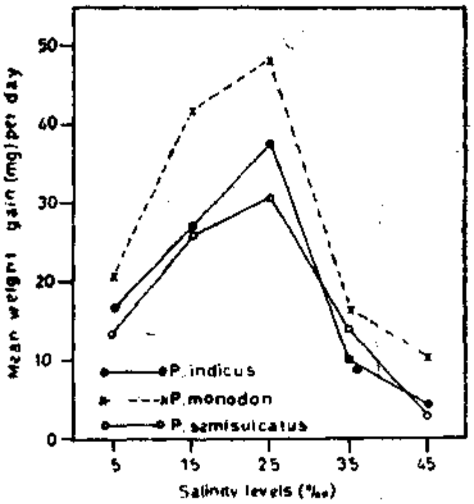

Fig. 7. Mean growth per day of prawns at different salinity levels.

The per cent survival (Fig. 8) was much higher at all salinity levels than what was achieved in other species. Even at high salinity levels, the survival rate was very high. Moreover, cent per cent survival was recorded at

5‰ and 15‰ levels indicating their preference for low salinities.

Penaeus semisulcatus

As indicated in Figs. 5 and 6 this species showed better growth at 25‰ and 15‰ levels, followed by 35‰ and 5‰ levels. Growth in this species was also much slower at 45‰ level (2 mg per day). The highest mean weight gain of 30 mg per day was recorded at 25‰ level and the lowest mean weight gain at 45‰ level. Survival rates in this species was comparatively poor at 5‰ and 45‰ levels, and the best survival rates were attained at 15‰ and 25‰ levels.

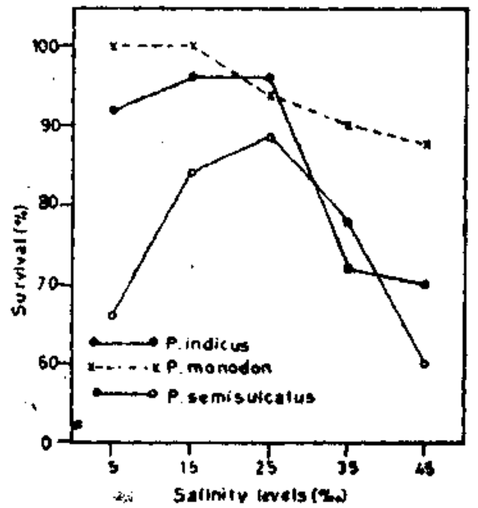

Fig. 8. Survival rates of prawns at different salinity levels.

Discussion

Although considerable growth was recorded at the tested salinity levels, the results clearly indicate the preference for low salinity levels for better growth by *P. indicus* and *P. monodon*. This is in conformity with the observations made in the nursery grounds, where postlarvae and juveniles of these two species occurred in a wide range of salinities, but with higher population density in low-saline areas (Raj, 1976). A number of other authors also have emphasized the requirement of low salinities by postlarval and juvenile penaeids for better growth and survival in the nursery areas (Gunter, 1950; Pearse and Gunter, 1957; Gunter *et al.*, 1964).

The higher growth and survival rates recorded at 15‰ and 25‰ by all the three species indicate their preference for these salinity levels, and probably these salinity levels may be their optimum required for better growth in the nursery areas too. The superior growth rates at these salinity levels may be due to their better efficiency of consumption and utilization of food as reported by Venkataramiah *et al.* (1974) for *P. aztecus*. Based on comprehensive studies on *P. aztecus*, Venkataramiah *et al.* (1974) stated that 'although the young shrimp can survive a wide salinity range, the best growth and survival rates were obtained in optimum salinities of 8.5 and 17 ppt.' Kinne (1970) also stated that 'in most of the euryhaline invertebrates, growth is restricted to a narrower range than survival is'.

Nair and Krishnankutty (1975) based on laboratory studies reported that the growth rate of *P. indicus* was significantly high in a salinity of 10‰ for postlarval stages and in a salinity of 30‰ for juvenile prawns. But in the present experiments best growth and survival rates were achieved at an optimum salinity range of 15 to 25‰ levels, compared to other salinity levels. Growth as well as survival in this species was adversely affected at high salinity levels of 35‰ and 45‰. *P. monodon* showed faster growth rates at all salinity levels compared to the other two species. The high survival rates achieved at all salinity levels indicate the hardiness of this species to a wide range of salinities. Among the three species studied, *P. semisulcatus* showed poor growth and survival rates at a very low salinity level of 5‰ and a hypersaline level of 45‰.

The distribution pattern of this species in Pulicat Lake also showed a similar trend. It was absent in the northern sector of the Lake during the monsoon season (October to December) when salinity was extremely low due to the incursion of freshwater through the rivers and during the pre-monsoon season (July to September) when the salinity reached very high levels coupled with consistently high temperatures and low oxygen levels (Raj, 1976). In the Cochin Backwaters also Rao and Kathirvel (1971) reported that the occurrence of this species was purely seasonal, disappearing during the monsoon season, when the salinity level was low in the backwaters.

The poor growth and survival rates at 45‰ level for all the three species of prawns indicate that, although prawns could be grown in a wide range of salinities, they do not do well in very high salinity levels, probably due to the stress caused by such high salinities. Grajcer and Neal (1972) obtained better growth rate at 32‰ level and poor growth at 50‰ level in *P. aztecus*, and they attributed this to the poor consumption of food at 50‰. Although data on food intake was not recorded, a similar trend of poor consumption of food at 45‰ level was observed for all the three species, during the experiments.

With reference to salinity relations of *P. aztecus*, Zein-Eldin and Aldrich (1965) stated that 'other factors, such as food or cover, are of greater importance than salinity *perse* in determining distribution, growth and survival of these animals.' But the results of the present experiments clearly substantiate the effect of salinity levels on the survival and growth of the penaeids, when identical conditions of temperature and food were available at all salinity levels. However, as far as distribution is concerned, the postlarvae and juveniles of all these species preferred a cover when salinity was favourable in the nursery areas (Raj, 1976).

Further studies on the combined effect of salinity, temperature, food quality and quantity and oxygen on the conversion efficiency, growth and survival would be of greater significance for understanding prawn distribution and for improvement of management practices in penaeid prawn culture.

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OBSERVATIONS ON THE MIXED CULTURE OF BRACKISHWATER FISHES AND PRAWNS IN A POND AT ADYAR, MADRAS

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Abstract

Experiments were conducted with milkfish, mullets and prawns with a view to have a preliminary information on how the stock-harvest manipulation influences the yield from a single brackishwater pond of 0.045 ha in area. Various methods of stocking and harvesting such as (1) single stocking and single harvesting, (2) single stocking and multiple harvesting, (3) multiple stocking and single harvesting, (4) multiple stocking and multiple harvesting were tried by conducting one experiment for each method. The combination of milkfish, mullets and prawns was used in each method. Different stocking rates such as 4,444/ha, 11,111/ha, 5,444/ha and 3,333/ha for milkfish ; nil, 5,555/ha, 6,800/ha and 2,644/ha for mullets and 20,000/ha, 16,666/ha, 29,443/ha and 37,777/ha for prawns were experimented with in the four methods respectively.

Multiple stocking and multiple harvesting when stocked with *Chanos chanos*, *Mugil cephalus* and *Penaeus indicus* resulted in the lowest yield of 680.4 kg/ha/year, the highest being 2,986.2 kg/ha/year from the single stocking and multiple harvesting in which *C. chanos*, *Liza macrolepis*, *P. indicus* and *P. monodon* were stocked.

A mixture of rice bran and ground nut oil cake in the ratio of 1 : 1 was used as supplementary feed in the 2nd and 3rd experiments at 5 to 10% of body weight for the fingerlings and growing fish and prawns. Hydrological characteristics of the pond water are also presented and discussed.

Introduction

Aquaculture in recent years has assumed great importance as a means of augmenting the production from water resources to fill the protein gap in the diet of the rural poor in the country.

Considerable know-how has been developed in respect of freshwater fish culture in recent past by adopting a technique involving culturing of six compatible species of Indian and exotic carps. The principle behind this system is to exploit all the natural food niches of the pond. In addition to enhancing the production of natural food in the pond by fertilisation (both organic/inorganic), supplementary feeding is also done in this practice. By this it has been possible to produce 7,284 kg/ha 8 months (Anon., 1975). Comparable production from brackishwater fish culture has not yet been achieved as brackishwater aquaculture is still in its infancy in our country.

Traditional brackishwater fish culture is prevalent in many parts of the world especially in the Far East. The age old practice being followed in India was to trap the young fish and prawns entering the fields with incoming tides and harvesting them after a lapse of 7 to 9 months (Jhingran, 1978). In Kerala coast, this is known as 'Pokkali' field prawn fishing and in West Bengal, it is called 'Bhashabada' fisheries.

The production obtained by these practices under uncontrolled conditions is obviously not comparable with that obtained in case of freshwater aquaculture. Adopting the techniques of freshwater fish culture in brackishwater fish farming with suitable changes would ameliorate the conditions of the rural poor in coastal areas of our country.

Recently it has been found possible to achieve good production of fish and prawns through brackishwater aquaculture. A production of 543 kg/ha/6 months of 'bagda' (*Penaeus monodon*) was reported from CIFRI farm at Kakdwip (Anon., 1975) while Haldar (1978) succeeded in breeding the same under controlled conditions by unilateral eye stalk ablation. Sunderarajan *et al.* (1979) have reported a good production of prawns and milkfish (1,437 kg/ha/6 months) through mixed culturing. Another significant advancement has been the development of the technology of mixed farming of different species. In a six species combination of prawns and fishes, a net production of 2,671 kg/ha/annum was achieved (Jhingran, 1978).

Evolving a technology for brackishwater fish and prawn culture suitable to the different regions of our long coastline involves regional knowledge and planning in respect of nature of soil, tidal influence, seed potentialities, optimum period of culturing, harvesting periodicity etc.

A few preliminary experiments on mixed culture of milkfish, mullets and prawns were conducted in a pond (0.045 ha) at Adyar, Madras, to find out how the stock-harvest manipulation influences the production in a seasonal pond.

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Material and Methods

The experiments were conducted in a 0.045 ha brackishwater pond at Adyar, Madras. The pond is more or less seasonal and stagnant in nature with considerable shrinkage in water level during summer. This pond was constructed several years ago and is partially loaded with silt, sewage muck and organic detritus. The depth during the period of experiments was about 0.50 m.

The young ones of *Chanos chanos, Liza macrolepis, Mugil cephalus, Penaeus indicus* and *P. monodon* were collected from Pulicat Lake, Adyar Estuary at Kovalam Bay and transported to Adyar in open containers for all the experiments. Four methods of stocking and harvesting such as (i) single stocking and single harvesting, (2) single stocking and multiple harvesting, (3) multiple stocking and single harvesting and (4) multiple stocking and multiple harvesting were tried by conducting one experiment under each in the same pond extending over a total period of nearly 3½ years, the period of each experiment ranging between 3 and 13 months. The species combination, duration of experiment, the stocking rates etc. for different experiments are presented elsewhere.

Supplementary feeding with a mixture of rice bran and ground nut oil cake in the ratio

1 : 1 was done at 10% of body weight on alternate days during the period of second and third experiments. The feed was broadcast over the pond. Feeding used to be discontinued whenever mortality of either fish or prawns was noticed usually following rainfall and resumed after the conditions improved *i.e.*, D.O. level increased.

Weekly water samples were collected between 0930 and 1100 hrs and analysed for dissolved oxygen, salinity, pH, free carbon dioxide, total alkalinity, phosphates and silicates. Simultaneous records of surface water temperature were maintained. Water and soil were analysed following the standard methods (APHA 1955 ; Piper, 1950).

Observations

The details of all the four experiments are shown in Table 1. The results of the analyses of physico-chemical features of pond water and soil are detailed in Tables 2 a and b.

Experiment I : Single stocking and single harvesting

C. chanos and *P. indicus* were stocked at 4,444/ha and 20,000/ha respectively. The experiment was conducted for a period of 3 months at the end of which 7.67 kg of *C. chanos* and 2.18 kg of prawns, amounting to a total of 218.9 kg/ha in 3 months with a survival of 59% and 34.7% respectively, were harvested. When projected for one year the production amounts to 875.5 kg/ha/year (Table 1). This production has been achieved without resorting to any supplementary feeding.

Experiment II : Single stocking and multiple harvesting

In this experiment, the grey mullet *L. macrolepis* was added to the other two. The stocking rates were slightly different, *viz.*, 11,111 (*C. chanos*), 5,555 (mullets), 16,666 (prawns) per ha. The experiment was carried out for a period of 6½ months. Though it is deemed to be single stocking, *Chanos* and mullets only were stocked on the same day while prawns were stocked about 10 days later. In the first harvest at the end of 3 months only prawns and *Chanos* were partially removed while the whole of the mullet stock and the remainder of the other two were taken in the second harvest. This yielded a production of 66.62 kg of *Chanos*, 3.42 kg of prawns and 2.75 kg of mullets from the pond which works out to a total of 1617.6 kg/ha/6½ months. The survival in this case was 66.2%, 24.0%, and 16.0% for *C. chanos*, *L. macrolepis* and *P. indicus* respectively. In other words a total annual production of 2,986.2 kg/ha was obtained. In this experiment, however, a mixture of rice bran and ground nut oil cake (1 : 1) was given as supplementary feed.

Experiment III : Multiple stocking and single harvesting

In addition to the above species, tiger prawn, *P. monodon* was also included in this experiment which was conducted for a total period of 13 months. Stocking was completed in 8 instalments spread over a period of 6½ months. The overall stocking rates for *C. chanos*. *L. macrolepis*, *P. indicus* and *P. monodon* were 5,444, 6,800, 27,777 and 1,666/ha respectively. At the final single harvest, 15.23 kg of *Chanos*, 21.11 kg of mullets, 1.09 kg of white prawn and 0.59 kg of tiger prawn were harvested with 43.7%, 78.8%, 5.1% and 14.0% survival respectively. When converted to per hectare per year the total production was 780.0 kg. As in the second experiment, here also artificial feeding was given.

Experiment IV : Multiple stocking and multiple harvesting

The species used in this experiment were *C. chanos*, *M. cephalus* and *P. indicus* at stocking

TABLE 1. *Stock-harvest details of fishes and prawns under mixed culture in a pond at Adyar*

Expt. No.	Species Stocked	Duration of Expt. (months)	Seed stocked in pond	Stocking rate per hectre	Average measuremens: Initial Size (mm)	Initial Wt. (gm)	Final Size (mm)	Final Wt. (gm)	No. harvested from pond	Total weight harvested (kg)	Percent-age of survival	Production per ha/year (kg)
I.	*C. chanos*	3	200	4,444	98.1	7.00	205.9	65.0	118	7.67	59.0	875.50
	P. indicus	3	900	20,000	49.0	0.45	106.5	7.0	312	2.18	34.7	
II.	*C. chanos*	—	500	11,111	85.8	4.60	—	—	—	—	—	
	,,	3 (app)	—	—	—	—	300.0	185.0	222	41.07	—	
	,,	6.5 (,,)	—	—	—	—	326·0	234.4	109	25.55	66.2	
	L. macrolepis	—	250	5,555	77.0	7.30	—	—	—	—	—	2986.20
	,,	6.5 (,,)	—	—	—	—	167.0	45.8	60	2.75	24.0	
	P. indicus	—	750	16,666	37.9	0.30	—	—	—	—	—	
	,,	3 (,,)	—	—	—	—	156.7	24.3	54	1 31	—	
	,,	6 (,,)	—	—	—	—	166.4	32.0	66	2.11	16.0	
III.	*C. chanos*	—	200	—	139.8	18.50	—	—	—	—	—	
	,,	—	45	5,444	202·0	51.00	—	—	—	—	—	
	,,	13	—	—	—	—	269.4	138.4	107	15.23	43.7	
	L. macrolepis	—	200	—	161.8	45.8	—	—	—	—	—	
	,,	—	82	—	94.7	16.0	—	—	—	—	—	
	,,	—	24	6,800	147.0	10.0	—	—	—	—	—	780.0
	,,	13	—	—	—	—	219.9	85.0	241	21.11	78.8	
	P. indicus	—	500	—	29.0	0.12	—	—	—	—	—	
	,,	—	750	27,777	26.2	0.17	—	—	—	—	—	
	,,	12 (app)	—	—	—	—	131.1	17.03	64	1.09	5.1	
	P. monodon	—	75	1,666	26.6	0.19	—	—	—	—	—	
	,,	6 (,,)	—	—	—	—	172.5	45.40	13	0.59	14.0	
IV.	*C. chanos*	—	150	3,333	116.9	10.33	—	—	—	—	—	
	,,	7.5	—	—	—	—	321.5	205.0	60	12.30	—	
	,,	4.5	—	—	—	—	282.9	191.0	60	11.46	80.00	
	P. indicus	—	900	20,000	36.6	0.33	—	—	—	—	—	
	,,	—	500	11,111	43.4	0.61	—	—	—	—	—	
	,,	7	—	—	—	—	137.3	17.4	77	1.34	—	
	,,	—	300	6,667	63.0	1.20	—	—	—	—	—	680.40
	,,	4	—	—	—	—	113.1	10.0	30	0.30	6.3	
	M. cephalus	—	119	2,644	71.8	4.7	—	—	—	—	—	
	,,	11	—	—	—	—	237.3	141.1	37	5.22	31·0	

Table 2 a. *Monthly average values of physicio-chemical features of pond water*

Parameters	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Water temp. (°c)	27.9	30.6	30.2	30.9	—	33.3	29.8	31.0	31.8	29.4	30.1	28.4
D.O. (ppm)	10.45	11.45	9.28	9.40	—	6.50	7.70	11.40	10.80	6.73	10.87	10.60
Salinity (ppt)	12.60	19.20	16.5	15.40	—	12.65	12.45	10.00	12.6	8.33	8.33	10.30
pH	8.00	7.90	8.50	8.40	—	8.30	8.30	8.30	8.00	7.60	7.40	N.D.
Free CO_2 (ppm)	Nil	Nil	Nil	Nil	—	Nil	Nil	Nil	Nil	1.20	Nil	N.D.
Total alkalinity (ppm)	90.00	110.00	130.00	160.00	—	180.00	152.00	84·00	80.00	65.00	60.00	N.D.
Phosphate (ppm)	0.30	0.40	0.20	0.40	—	0.40	0.30	0.40	0.69	0.72	0.90	0.18
Silicate (ppm)	3.00	2.40	1.60	2.80	—	3.00	2.20	3.00	4.00	4.60	4.80	6.00

N.D : No data

Table 2 b. *Average values of physicio-chemical features of pond soil*

Months	Physical		Chemical					
	Sand	Silt	Clay	Available phosphate mg/100 gm	Organic Carbon %	Free $CaCO_3$ %	Chloride %	pH
May	70.0	10.5	19.5	2.9	0.54	2.1	1.3	7.6
June	68.5	10.0	21.5	2.3	0.63	2·0	1·3	8.2
September	—	—	—	6.0	1.11	2.1	1.4	8.0
October	—	—	—	6.8	1.46	2.4	1.3	7.8
November	—	—	—	6.0	1.23	2.1	1.3	7.8

rates, 3,333, 2,644 and 37,778/ha respectively. The stocking was accomplished in 5 instalments and the harvesting was done on 2 occasions, the total period of experiment being one year. No supplementary feed was given. The total production achieved was 30.62 kg/12 months of which *Chanos* contributed to 23.76 kg mullets 5.22 kg and prawns 1.64 kg the percentage survival being 80.0, 31.0 and 6.3 respectively. Since the period of experiment was one year, the total production works out to be 680.4 kg/ha/year.

The physico-chemical characteristics of water and soil such as temperature, dissolved oxygen, salinity, pH, free CO_2, total alkalinity, phosphates and silicates of water and percentage of sand, silt and clay, available phosphate, organic carbon, free $CaCO_3$, chloride and pH of soil were recorded during the course of the study. The monthly averages of the same are presented in Tables 2 a and b. Temperature ranged between 27.9°C in January and 33.3°C in June, salinity between 8.33 ppt (October and November) and 19.2 ppt (February) and dissolved oxygen between 6.5 ppm (June) and 11.45 ppm (February). The other parameters did not show wide fluctuations except total alkalinity which varied between 60.0 ppm (November) and 180.0 ppm (June).

During the second and third experiments sporadic cases of mortality were observed following sudden rainfall. On such occasions, physico-chemical characteristics were recorded with a view to pin-pointing the causative factors responsible for the mortality. It was interesting to observe that mortality was concomitant with low values of dissolved oxygen which was more pronounced during early hours of the morning.

Discussion

The experiments detailed in the foregoing account were of a very preliminary nature mainly aimed at evolving techniques for utilisin gsuch seasonal ponds for producing standard fish and prawn. From the experience gained, it can be inferred that short-term culture of 3 to 6 months is more desirable than prolonged rearing. This is in agreement with the observations of George *et al.* (1968) in paddy field prawn culture and Jhingran (1978) on *P. monodon* culture at the C.I.F.R.I. farm, Kakdwip.

Multispecies culture has proved more productive than monospecies culture both in fresh and brackishwater because of the comparatively superior utilisation efficiency of a number of species tapping the different food pockets in the ecosystem. Das (1978) has elucidated this point as far as brackishwater culture is concerned by giving the production figures of *P. monodon* when cultured alone (1000 kg/ha/yr in 3 crops) as against culturing it together with mullet (2600 kg/ha/yr). The present observation eloquently proves the above view especially in the second experiment wherein *Chanos* was also included resulting in a production of about 3000 kg/ha/yr. This further points to the desirability of judiciously increasing the number of compatible species with a view to further enhancing the production as is accomplished in the freshwater composite culture of carps.

In the same experiment by repeated harvests, table sized fishes and prawns were removed leaving the smaller ones to grow faster utilising more space and food resources. Moreover, removal of larger specimens improves the conversion efficiency of the population.

As already mentioned, short-term culture with repeated harvests was found to yield very good production. Conversely, the same when done over a longer period did not prove to be equally productive as is observed in the last experiment. It is quite possible that this also could have resulted in equally good production, if restricted to a shorter period. Possible reasons for less production in the last two experiments were the reduced volume of water during the later part of the experiment and probably accumulation of external metabolites. Together with the reduction in volume of water, the concentration of metabolic wastes has increased to such levels as to retard the normal growth of the stock. The paddy field prawn fishing in Kerala is in many respects comparable to the last experiment, the main differences being the shorter periodicity of stocking and harvesting and also the accompanying exchange of water.

The stray instances of mortality in the second and third experiments mentioned earlier are of significance because, they have occurred immediately after sudden rains. This might probably have happened due to the sudden cooling and sinking of surface water bringing the oxygen deficient bottom water to the surface. Due to the heavy load of silt and debris accumulated over a long period in the pond and the organic muck derived from the garbage dumps around, the water at the bottom is likely to be polluted by CO_2 and other foul gases. This also would have affected the fish in the process of mixing. It is noteworthy that during certain periods of fish kill, CO_2 was noticed in the surface waters in addition to the very low dissolved oxygen (1.6 ppm). Raghvan *et al.* (1977) have reported an instance of fish mortality in Byramangala reservoir.

These experiments have shown that even small seasonal stagnant ponds can be well utilised for producing useful fish and prawn. This is not to be always taken with a high level of profit motive but, as beneficial to rural marginal farmer as it can provide a certain amount of badly needed protein in the day to day ration of himself and his family (Tubb, 1967). Extensive adoption of such subsistance level fish farming all along the long coastal regions can go a long way in augmenting the overall fish production in our country and also improve the socio-economic conditions of the rural poor.

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SOME PROBLEMS IN COMMERCIAL CULTURE OF MARINE PRAWNS IN INDIA

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Abstract

Although experimental work is being carried out on commercial cultivation of marine prawns at a few centres in India, intensive culture technology to suit the varying ecological and hydrobiological conditions in different parts of the country is yet to be developed and perfected. One of the constraints for increasing stocking density of prawns for obtaining maximum production per unit area is in adequate water replenishment on which depend the vital factors affecting the well-being of the stock. As prawns usually like to consume natural food items like algae rather than artificial food supplied such as pellets, an attempt to enhance their growth and fatten them by the latter is beset with difficulties, unless they are equally nutritious and well balanced. Another constraint in intensive culture of marine prawns is the havoc caused by predators, particularly carnivorous fishes. The present paper examines these problems and suggests ways and means of overcoming or reducing them.

Introduction

Among the two general kinds of prawn cultivation being practised in different parts of the world, 'extensive culture' involves operations in more or less natural amenities available, rather indiscriminate stocking allowing entry of even undesirable organisms inside the culture system and is devoid of proper management procedures. The more scientific and systematic method of cultivation called 'intensive culture' involves elaborate construction of culture ponds, selective stocking with the most desirable species and implementation of management procedures. In the former method, production is rather low but in the latter it is quite high. In India, where there are vast scope and potentialities for commercial culture of marine prawns, only extensive culture is being practised in the 'Pokkali' fields of Kerala, 'bheris' of West Bengal and 'Khazan' lands of Goa. However, in the wake of increasing demand for marine prawns both for internal consumption as well as for export purposes, attempts are being made at present for their intensive culture; and experimental work and/or pilot projects are being undertaken at a few centres by research organisations as well as commercial firms. An intensive culture technology has been developed in countries like Japan (Shigueno, 1975). Unlike Japan, India is a vast country with an extensive coastline of about 6,100 km with various agro-climatic and soil conditions, and localized ecology and hydrobiology. As such, the intensive culture technology being evolved in various regions is bound to differ from one another. However, there are a few general problems which are likely to be faced in intensive culture operations wherever it is practised in relation to the prevailing conditions and in the context of the principal aim of enhancing production in intensive culture. The present paper examines some of these problems faced by the author in Tuticorin and Porto Novo during 1975-79 and suggests ways and means of overcoming or reducing them.

Water replenishment

One of the constraints for increasing stocking density of prawns in intensive culture systems for obtaining maximum production per unit area is in adequate water replenishment. It is well realized at present that the vital factors affecting the well-being of culture stocks such as amount of oxygen available, temperature of pond water, calcium content present, etc. are closely linked up with water management. In intensive culture in Japan it was found (Shigueno, 1975) that no simple stocking formula could be prescribed without taking into consideration the quantity of dissolved oxygen present and the rate of circulation of pond water. Experience has shown that if water temperature is 28°C, dissolved oxygen content is at 80% of saturation (6.3 ppm) and if 10% of the amount of water could be replaced every hour, then the stocking density could be made at a level to yield 0.11 kg/sq. m, allowing a mortality of 30%. On the other hand, if 33% of water could be replaced every hour under the same conditions, the stocking density could be increased to a level to yield 0.5 kg/sq. m, which in terms of a hectare would amount to 5,000 kg. From these facts it is obvious that for increasing prawn production by intensive culture, it is imperative to ensure effective water management in culture ponds.

The most inexpensive method of water replenishment for culture ponds is by making use of the tidal amplitude prevailing in the locality. In India, tidal amplitudes are usually more during the second half of the year than during the first. Also, south of about 14° latitude, the amplitudes are usually in the range of 1 to 1.5 metres, while north of this latitude the amplitudes are more. Besides, the topography of the site selected for culture in relation to prevailing tidal amplitudes throughout the year should be carefully examined for ensuring effective water exchange. Taking these aspects into consideration it appears that for constructing culture ponds in a state like Tamil Nadu the ponds should be deep enough for holding adequate quantity of water. Also, fool-proof provisions should be effected for sufficient renewal of water, such as a separate outlet, installation of inexpensive wind-mills, etc. Cases have come to notice where seepage has been taking place even in clayey areas, resulting in quick loss of water. In such areas, the ponds should be excavated in such a manner that the pond bottom is at a level lower than the substratum of the source from which water is drawn for culture. Alternatively, durable liners such as made of synthetic material and inexpensive sealents could be used to make the culture ponds free from seepage and rapid loss of water.

In addition to effecting adequate water replenishment in the above lines, the amount of oxygen present in the pond water may be kept at optimum levels by operating artificial contraptions also. Aerating water in commercial culture ponds is commonly practised in intesive cultivation of prawns, eels, etc. in countries like Japan. Development of indigenous contrivances for aerating pond water would go a long way for solving the problem of oxygen availability in ponds and lead to higher production.

It was observed that ponds constructed in areas which enjoy strong winds have the advantage of some quantity of atmospheric oxygen diffusing into the water. Therfore, while preparing layout of culture ponds it is essential to bear in mind the direction of winds in different seasons of the year and plan the layout in such a manner that the pond water is, exposed to maximum wind action. However, on days with windless weather, lack of adequate diffusion of atmospheric oxygen was found to result in deoxygenation of pond water and distress for cultre stocks. On such occasions, it is essential to exchange the water immediately or aerate it artificially.

Feeding culture stocks

In temperate regions of the world there is rather less natural productivity in embanked areas and estuarine regions. On the other hand, in tropical zones under blessings of enough sunlight and natural and man-made fertility available, productivity of water masses is rather high (Bardach *et al.*, 1972), leading to algal and diatom blooms which in their turn result in zooplankton production. This natural productivity is a factor of great advantage in extensive culture of prawns, as there is lesser need for providing supplementary food. On the other hand, in intensive culture operations, the aim is to enhance growth and production of culture stocks by providing artificial well-balanced food. And, since prawns are observed to prefer natural food items present in culture ponds to artificial food pellets supplied, the presence of the former in large quantities is likely to prejudice the success of intensive culture operations. It may be noted in this connection that it is rather impractical to prevent the growth of algae and diatoms, since natural fertility factors as well as the nutrients added to the system in the form of left-overs from artificial food supplied serve to increase the production of algae, diatoms, etc.

One way of reducing natural algal growth is to strike a balance at which the artificial food supplied is just sufficient for the growth of the culture stock, without allowing any residue to get into the pond ecosystem. In this connection, it is essential to ensure that the artificial food supplied remains intact in the bound condition till it is consumed completely by the prawns. For this purpose, an effective binding agent such as gluten or agar-agar or even some synthetic binder in adequate concentrations is an essential prerequisite. The pelletted food could be compounded in such a way that its taste should be made equally acceptable for the prawns as natural food available. In this case, some amount of fundamental research appears to be necessary. Besides, periodical estimation of the stock present in the ponds may be made for broadcasting only the amount of food required by the stock.

Environmental conditions

Unlike *Penaeus indicus* and *P. monodon* which have a wide range of tolerance to such environmental factors like salinity, species such as *P. semisulcatus* is less euryhaline and will not be able to tolerate low saline conditions ranging from 15 to 20‰. Also, sudden lowering of salinity accompanying heavy rains or influx of fresh water was found to affect culture stocks of *P. semisulcatus* at Tuticorin and Porto Novo. When pens or ponds constructed in areas which are prone to such adverse factors are stocked with *P. semisulcatus* the results are most likely to be disastrous. Therefore, it is an essential prerequisite that culture of such species is carried out in localities and during seasons which are free from sudden changes in salinity values.

Similarly, high values of temperature were observed to cause distress to culture stocks, especially during summer months (April-June), when temperature in the afternoon hours rises to 35-40°C. If the culture ponds, are deep enough or provided with trenches for the shelter of the stock, it would serve to protect the population and reduce mortality. In addition, to this, shelters may be provided in the form of tree branches, bamboo twigs, coconut leaves, palmyrah leaves, etc. for prawns to get shelter. Also, jets or fountains of water could be provided for cooling the ponds on days of excessive heat.

Prawns which were cultured in ponds having a slushy substratum were observed to register much less growth than those stocked in ponds with a firm substratum such as hard clay and sand. It was also found out that quite often prawns cultured in ponds of the former category had failed to harden the shells, pointing out that the amount of calcium present in such an environment is not sufficient for their growth, moulting and normal hardening of the shell. Therefore, it is advisable to avoid such areas for prawn culture operations, but, if such areas could not be avoided, steps to improve the environment should be resorted to such as conversion of the slushy substratum into one of hard clay or sand. Alternatively, adequate amount of calcium may be provided in the supplementary food supplied to the culture stocks or calcium compounds may be applied to the ponds from time to time, without adversely affecting the hydrology of the pond. Some amount of basic research on calcium requirements of the important species at various levels of their growth stages and assimilation under various hydrobiological conditions in the culture site is essential in this regard.

Fish Predators

Predatory animals, particularly carnivorous fishes, usually cause considerable alarm in intensive culture of marine prawns. Even in countries like Japan, fish predators have been posing serious problems and many a venture is stated (Shigueno, 1975) to have met with disastrous ends due to the failure to solve this one problem. In India, the predatory fishes usually found in prawn culture ponds are *Lates calcarifer, Elops saurus, Epinephelus, Therapon, etc.* In addition to these, crab predators *Scylla serrata* and *Portunus pelagicus* have been observed, particularly the former in large numbers. Even after killing predators by chemical fish poisons or organic fish toxicants well before stocking the ponds, these harmful organisms were observed to find their way into the culture ponds by penetrating mesh screens in their early developmental stages and grow rapidly. For instance, *Elops saurus* was found to grow to a size of 12-15 cm total length within 45 days.

One way of preventing the entrance of predatory fishes into culture ponds is to mechanically obstruct their penetration by providing a series of fine-meshed nets across the passage of water. In this connection, care should be taken to ensure that the meshes of the net screens are smaller than the sizes of the eggs, larvae, etc. of predatory fishes. Experience has shown that this is an effective method. Another way of solving the problem of predatory fishes after they have found access into the ponds is the application of agents containing such toxicants which when applied in certain concentrations are lethal only to bony fishes but do not have any bad effect on prawns. These toxicants are rotenone, saponin contained in derris powder, teaseed oilcake and mahua oilcake. In this connection, the approximate age of the predator at which it becomes actively predaceous should be known in order to determine the periodicity of application of the toxicant.

The only method of eradicating crab predators is to trap them by using simple trap-bait devices, such as the one used for capturing *Scylla serrata* in certain areas (Shanmugam and Bensam, MS).

Remarks

Shigueno (1975) has rightly pointed out that 'for development of shrimp culture into a stabilized industry, three factors must not be excluded from serious attention, namely, the breeding of fry, the control of natural enemies and the problem of feeding which includes the management of pond water'. Among these three factors, production of prawn seeds by artificial propagation has already been achieved in India through the recent researches of the Central Marine Fisheries Research Institute (CMFRI, 1978); and some agencies are on the way of commercialisation of prawn seed production at present. But, the problems of controlling natural enemies and feeding culture stocks in the context of natural productivity and management of water replenishment in various ecosystems still remain as important problems to be investigated and solved successfully.

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THE CULTURE OF MILKFISH, MULLET AND PRAWN IN AN EXPERIMENTAL MARINE FISH FARM AT TUTICORIN

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ABSTRACT

Preliminary experiments were carried out in fish farm of salt pan reservoir for polyculture of *Chanos chanos, Mugil cephalus* and *Penaeus indicus*. The seeds were collected from nearby estuarine areas and stocked at different intensities. The important problem facing the experiment was the prevalence of competitors and the maintenance of quality of water. Of the three varieties cultured, mullet appeared to grow well with better survival rate resulting in an increased rate of production. Marketable size at 31 cm was attained in a period of 9 months. A marked difference in the rate of growth and production of the species under culture was well noticed in three sets of experiments carried out during 1977-1979. The estimated rate of production in polyculture increased from 499 kg to 731 kg/ha/year in the present status. Hydrological conditions of the farm were examined briefly. The results of the experiments appeared to be encouraging for extensive culture practices. Possibility of enhancing the production by increasing the stocking density and by resorting to intensive management procedures are

INTRODUCTION

Much has been said in the recent years about aquaculture in different ecosystems such as the ' pokkali ' fields of Kerala, ' bheries ' of West Bengal, ' gazani ' farms of Karnataka and ' khazan ' lands of Goa (Alagarswami, 1978; Muthu, 1978). However, importance for the productive utilisation of derelict salt water areas was recognised only in recent years in India. Information on the culture of fishes in salt pan reservoirs is very scanty. Suseelan (1975) studied in detail an elegant system of culturing *Penaeus indicus* in the salt pan reservoirs adjacent to Manakkudy estuary in Kanyakumari District. Nair *et al.* (1974) examined the possibilities of culturing *Chanos chanos* under controlled conditions in salt pan areas at Tuticorin. Subsequently, Bensam and Marichamy experimented on the culture of the milkfish in the salt pan areas at Veppalodai, Tuticorin. Realising the immense scope for salt water fish farming a series of three experiments were carried out, the first in 1977, second in 1978-79 and the third one during 1979. In the present pioneering work on polyculture, compatible, euryhaline and fast growing species like *P. indicus, Mugil cephalus* and *C. chanos* were selected in the context of augmenting income along with the normal production of common salt and effective utilisation of the available ecological niches. Another advantageous factor for culturing these species was the availability of seeds during the same period around March-May.

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AREA AND ENVIRONMENTAL CONDITIONS OF THE FARM

The location of the site selected for the experiments was adjacent to the spot shown in earlier publication by Nair *et al.* (1974). Veppalodai Salt Corporation is nearer to Kallar estuary and about 2.5 km from the sea. There are about 81 hectares of low saline reservoirs in the midst of vast area of salt producing pans.

The ideal period for the preparation of pond would be December-January since the northeast monsoon happened to be the off season for salt production. The entire reservoir was first completely drained and allowed to dry for a month until the clayey reservoir bed develops fissures. The sun drying aids in the mineralization of organic material left at the pond bottom, cracking of the soil allows release of noxious gases and greater penetration of oxygen into the bottom. A culture pond with an extent of 91.5 × 30.6 m (2800 m^2) was developed since the reservoir was too extensive for the present experiment (Plate I A). The pond was deepened to 1 m so that it can always retain a minimum of 0.6 m of water. Sufficient depth was an essential prerequisite in this area to keep away the predatory birds. The pond was connected by a feeder canal from the pumping station situated on the bank of the estuary. The pond was fitted with wooden sluice of 1.2 × 0.9 × 1.2 m made according to the shape of the bund. It had a wooden shutter as well as sliding frame of velon screen to regulate the flow of water inside the pond. While the sluice served as an inlet, two PVC pipes of 10 cm diameter were fitted on the other side of the pond to serve as outlets. No organic or inorganic manure were added to fertilize the pond as it was thought that the same would affect the quality of the production of common salt. Supply of sea water was normally regular from late January to September and suspended at the onset of NE monsoon. Special arrangements were made to pump sea water, particularly to feed the culture pond in the off season.

Data regarding the seasonal fluctuations in water characteristics gathered for the period of culture are given in Table 1. The monthly average values of surface temperature, dissolved oxygen and salinity of the experimental area were always higher than that of the open sea. The variations in salinity follow more or less the trends of temperature. An increase in temperature in summer months resulted in a rising salinity and this peak was uniformly noticed in all the three years. A secondary peak in temperature was noticed during September/October coinciding with the increased salinity of the environment. A fall in temperature and salinity was noticed after the onset of NE monsoon. The dissolved oxygen fluctuated in the range 3.8-6.9 ml/l. Significant difference in salinity was noticed during the three years. In 1977, the salinity was steadily increasing from 37.58‰ in January to a maximum of 50.32‰ in September. It remained high above 42‰ from May to October. In the following year 1978, high values of salinity in the range 44.94 -52.76‰ were recorded more or less during the same period, May to August. It should be noted that these corresponding months are the active period for the stock to grow well following their stocking in March/April. Although the cultivable species were euryhaline, better growth and production had been recorded in slightly low saline media. Salinity is an important factor of the environment in culture practices. In view of this efforts were made in the third experiment in 1979 to maintain the salinity of farm on the lower range. Adequate number of inlet and outlet pipes were laid at suitable levels for a continuous flow of sea water inside the pond to facilitate flushing. Consequently, the salinity was far below the average values of earlier experiments. Besides the peak noticed in two dry seasons, it varied from 29.76‰ to 39.78‰. The average value of pH

TABLE 1. *Hydrological observations* made at Veppalodai Fish Farm*

Months	1977				1978			1979		
	Temp.°C	O_2ml/l	S‰	pH	Temp.°C	O_2ml/l	S‰	Temp.°C	O_2 ml/l	S‰
January	26.0	4.6	37.58	8.08	—	—	—	27.7	5.7	38.48
February	26.2	4.7	38.18	8.10	—	—	—	28.0	6.8	73.30
March	26.2	4.6	38.90	8.17	28.9	4.3	52.76	30.0	7.1	36.31
April	28.9	4.6	39.87	8.13	28.8	3.8	44.94	33.0	4.5	39.70
May	28.2	4.8	46.70	8.20	28.9	4.2	49.76	29.2	4.4	42.68
June	27.9	5.9	44.80	8.35	28.1	3.9	45.9	30.3	4.4	39.78
July	26.9	4.9	42.20	8.28	28.5	6.9	50.79	29.7	4.4	39.00
August	27.3	5.5	42.23	8.30	26.5	6.6	47.98	26.0	4.8	38.37
September	30.1	5.8	50.32	8.35	28.0	5.6	40.56	28.0	3.8	35.14
October	30.4	5.0	42.28	8.30	27.5	5.4	29.37	31.0	5.9	43.72
November	29.8	5.1	36.87	8.30	29.5	4.9	34.34	27.0	5·5	29.76
December	26.6	4.6	27.18	8.25	27.5	4.2	31.24	28.0	4.8	32.52

*Observations at 0930 hours.

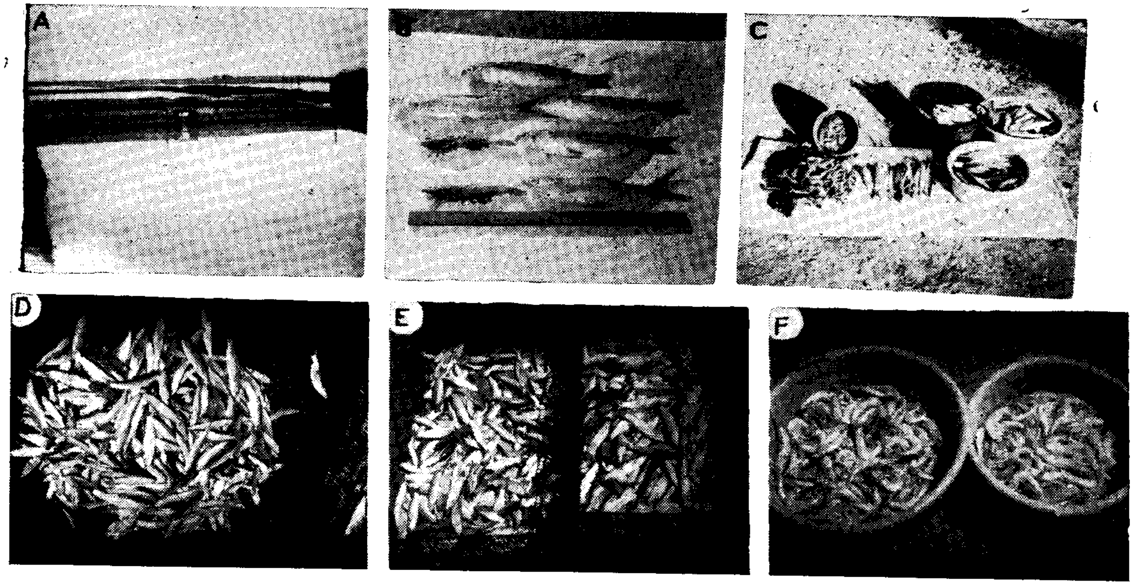

PLATE I. A. General view of fish farm; B. The average size of *C. chanos*, *M. cephalus and P. indicus* harvested in March 1979; C. Combined production of 2nd experiment; D—F. *C. chanos*, *M. cephalus* and *P. indicus* harvested in 3rd experiment.

was around the optimum requirement. Among the plankters, copepods, *Lucifer*, *Acetes*, and mysids were noticed. Phytoplanktonic organisms though scarce were comparatively more during August-November. The common diatoms were *Coscinodiscus*, *Thalassiosira*, *Asterionella*, *Pleurosigma* and *Nitzchia*. A low representation of planktonic organisms was noticed in the later two experiments.

Culture Experiment

Source of seed: The source of seed supply of the species used for culture was mainly from natural habitats. Seeds were available in this region from April onwards. Mullet seeds were collected from the intertidal flats, mud pools and mangrove swamp creeks of Tuticorin coast. Seeds of milkfish were collected from the estuarine regions of Kallar, Arasalodai and Tambraparani and also in backwaters near Tiruchendur and Vaninokkam. The shoal of milkfish fry was identified in their natural habitat with the clockwise movement in shallow regions. Collections were usually made in the mornings following the turn of tides. Simple drag nets of different sizes, made of mosquito netting cloth were used in the collection. After each haul the fry were scooped with a bowl and transferred into a bucket and then oxygen-packed in polythene bags, using clear water collected from the same area. Depending upon the size of fry, 500-1000 fry were packed in each bag. The rate of mortality due to transportation of seeds was negligible in the case of milkfish while mullet seeds had a mortality of 20-30%, probably due to the higher packing intensity and larger size of seeds. Seeds of *P. indicus* were collected from Kallar Estuary during March-May near sluice gat fitted in reservoirs near the pump house.

Stocking operation: Seeds of mullet and milkfish were released in separate 'hapas' of size 200 × 100 × 50 cm for acclimatization. This was necessary as the salinity of the area of collection differed from the conditions of the pond. Unwanted species were eliminated. The details regarding the period of stocking, number, their weight, the size range, the mode, the average length and weight of the seed released in 3 sets of experiments are given in Table 4. Single-size stocking method was followed. *P. indicus* seeds were also stocked with the above two non-predatory finfishes in the polyculture pond at a higher stocking rate of 1.5 to 7.6 seeds/m^2. Importance was given to culture of prawn than the others because of its commercial value. In order to see the difference in growth rate and production potential stocking intensity was increased from 1.5/m^2 in the first experiment to 4.3/m^2 in the second and 7.6/m^2 in the last experiment. However in the case of other species the stocking was according to the availability of seeds.

The modal size of mullet seeds was 40-69 mm while the dominant seeds of milkfish measured 29-47 mm during the three sets of culture. Stocking period was usually from March-May. To ensure good survival juvenile prawns with the mean size of 51-70 mm were stocked.

Farm management: The aim of the first experiment was to assess the production potential of the polyculture in confinement under existing conditions in the area and so artificial feeding of the stock was avoided or limited to the minimum whenever the supply of water was suspended. A variety of predatory birds like *Pelican*, *Flemingo*, stork, etc. were driven away by firing crackers. The depth of water in the farm was maintained by regular flow through sluices. Velon screens were cleaned with brush on alternate days to prevent clogging of meshes with silt etc. They were changed periodically when holes and tears were formed to prevent the entry of unwanted fishes into the pond and escape of the stock from the pond. Since the wooden sluice damaged the bund beneath it, the sluice was removed and in the subsequent experiments adequate number of PVC pipes were laid. Thus the problem of predatory fishes in the farm was minimised and with regular flow of water, the salinity also fluctuated only within a narrow range. Flowing water system would be advantageous for polyculture. Before carrying out the third experiment in 1979, the pond was drained completely and desilted. A silt layer more than 5 cm in thickness was considered to be detrimental to health of prawns (Muthu, 1978). Then the pond was allowed to bake in the sun till some cracks appeared in the bottom. Subsequently better results were obtained.

A major problem faced during the period of culture was the supply of sea water from October onwards. With the onset of monsoon, the Corporation stopped pumping the sea water. In the same period reclamation works in the canal was attended to. Only on special requests, estuarine water was pumped or otherwise managed to retain the water diluted by closing the outlets of the pond. However, no depletion in oxygen was recorded due to this arrangement. When the nearby reservoirs became dry or stored with high brine water a number of crabs like *Scylla serrata*, *Thalamita crenata* as well as sea snakes and eels migrate and find shelter in low saline culture pond causing damage to the stock. Crabs which were highly predaceous on newly moulted prawns, were eradicated by using hoop nets with suitable baits like gill rakers and other gutted wastes of fishes. One of the major jobs associated with the maintenance of farm was the removal of predatory fishes such as *Lates calcarifer*, *Elops saurus*, *Eleuthronema tetradactylum*, *Platycephalus* sp. and *Therapan* spp. with gill nets to some extent on the occasions of sampling.

The types of polyculture farming that depends solely or mostly on natural food have comparatively lower yield per unit area than those depending on artificial feeds. The availability of natural food in the farm was not sufficient since fertilization was avoided in the beginning. As pointed out by Jhingran and Natarajan (1972) detritus formed the dominant food of *M. cephalus* followed by algae, diatoms and occasionally zooplankton. Supplementary feeding was practised in the second and third experiments of culture which consisted of material readily and cheaply available, especially farm byproducts such as rice bran, wheat bran, groundnut oil cake, tapioca powder crustacean powder made out of dried *squilla* and prawn heads and fish meal powder. The last two combinations were specially added to prawns along with the paste of rice bran and tapioca powder. Occasionally chopped trash fishes were also supplied. For finfishes the above supplemental feed sprinkled with water was sprayed over the surface of the pond. During the last phase of the last experiment transportation to the farm was cut due to heavy rains and supply of feed was discontinued.

Harvesting was carried out by drag net fitted with stakes at intervals, after partly draining the water from the pond in the first year. In the following attempts a diesel pump was used to drain the pond completely and harvesting was effective when the stocks were removed by hand picking. Seine net was also used when the pond remained drained.

Growth

Growth rates of the species cultured in the farm have been studied by following the progression of modes in the size frequency distribution of samples sampled at different stages and at harvest. In Table 2, the overall growth of *P. indicus*, *M. cephalus* and *C. chanos* cultured in three different experiments during 1977-79 in salt pan experimental farm is presented. The actual period of culture for these three species was not uniform and hence monthly average growth rate was determined from overall progress to see the difference in growth from year to year and species to species. A growth rate of 10.3 mm in *P. indicus* was attained in 1979 as compared to the earlier experiments, probably due to short period of culture. It may also be pointed out that in 1979, the quality of water particularly salinity remained in a narrow range of 35-39‰ in most of the months. *C. chanos* showed a fast rate of growth. The seeds stocked at 42 mm during April 78 progressed to 346 mm in March 79 showing a growth of 304 mm in 12 months. *M. cephalus* stocked at mean size of 40 mm progressed to an average length of 314 mm indicating an overall growth of 274 mm in 9 months during the second experiment. (Plate I B).

The monthly rate of growth between different stages was estimated and the growth pattern of cultured species for the year 1979 is presented in Table 3. In *P. indicus* the estimated average growth upto 83 mm size was 16.3 mm per month. Till it reached 123 mm the growth

TABLE 2. *Growth of different species cultured in salt pan reservoirs*

Species	Number of experiment	Modal size at stocking (mm)	Modal size at harvest (mm)	Period of culture (months)	Growth (mm)	Rate of growth mm/month
P. indicus	1	70	130	9	60	6.7
	2	51	160	12	109	9.1
	3	58	126	6	68	10.3
M. cephalus	1	40.6	226.9	7	186.3	26.6
	2	40	314	9	274	30.5
	3	69	220	7.5	151	20.1
C. chanos	1	50.5	277	7	226.5	32.4
	2	42	346	12	304	25.3
	3	29	215	7.5	186	24.8

TABLE 3. *Growth pattern of species cultured during* 1979

Species	Initial observation		Subsequent observation		Interval between observation (days)	Growth (mm)	Rate of growth (mm/month)
	Sampling date	Modal size (mm)	Sampling date	Modal size (mm)			
P. indicus	3. 5.79	58	18. 6.79	83	46	25	16.3
P. indicus	18. 6.79	83	8.10.79	123	112	40	10.7
P. indicus	8.10.79	123	17.12.79	126	70	3	1.3
M. cephalus	22. 4.79	69	18. 6.79	122	57	53	27.9
M. cephalus	18. 6.79	122	8.10.79	192	112	70	18.7
M. cephalus	8.10.79	192	17.12.79	220	70	28	12.0
C. chanos	26. 4.79	29	18. 6.79	90	53	61	34.5
C. chanos	18. 6.79	90	8.10.79	200	112	110	29.5
C. chanos	8.10.79	200	17.12.79	215	70	15	6.4

rate was only 10.7 mm and very much low afterwards. *M. cephalus* exhibited a fast growth rate, 27.8 mm/p.m till it attained the size of 122 mm TL and thereafter at the rate of 18.7 mm upto 192 mm. Beyond that size the growth rate accounted to be was 12 mm only. *C. chanos* showed a still faster growth in the beginning. Upto 90 mm size the milkfish grows at the rate of 34.5 mm/p.m and declined to 29.5 mm/p.m to reach the size 200 mm and then it was very low. The slow rate of growth noticed in finfishes during the last phase may be due to irregular supply of supplemental feed in November-December.

Survival and Production

The results of the polyculture experiments carried out in fish farm in the salt pan reservoir during 1977-79 are presented in Table 4. In the first experiment the rearing period was 7-9 months whereas in the second experiment the culture period extended to a maximum of 12 months. Experimental period was very much reduced in the final observation to 6.5-7.5 month only resulting in a better survival rate for finfishes. Added to this, no predators were collected among the harvested stock in the third experiment whereas in the harvest in the year 1977, 2 snakes, eel fish, 2 crabs, 2 *Platycephalus* and 7 *Lates calcarifer* weighing about 3 kg were collected and in the second experiment 2 *Elops*, 1 *L. calcarifer*, 2 eels and crabs were found. The yield in the first experiment would have been better but for the entry of predators through the damaged wooden sluice. The survival rate of the prawns stocked in the rearing pond was affected obviously by many conditions among which the size of the seed at the time of stocking was of high significance. In the first experiment, *P. indicus* with average size of 70 mm at the rate of 1.5 seed/m^2 was stocked. The size was considerably big and stocking intensity was also low as compared to the later experiments and so a better survival of 22.4% was attained. In the second experiment the size of the prawn was only 51 mm and the period of earing was long (12 months) resulting in low survival rate of 8%. In the third experiment, although the rearing period was short, the size of the seed was small coupled with a high intensity of stocking at 7.6 seed/m^2 which ultimately resulted in poor recovery. Over stocking, that too when the quality of water was slightly above the normal, resulted in loss of stock as they are prone to cannibalistic tendency. In general, the survival rate depended upon the period of culture, size and stocking intensity of seed in the case of prawns. For assessing the rate of production, details of the number of prawns stocked and harvested during the three sets of experiments given the Table 4, were examined. A gradual increase in the species-wise production as well as combined production (Plate I C) was possible by improving the technique of management such as the preparation of pond, maintenance of water quality, control of predators, adjustment of period of culture, practice of supplementeal feeding etc. In the third experiment the annual production per hectare amounted to 731 kg (Plate I D, E, F) although the period of culture was less. Unfortunately, the water supply was suspended by the Corporation in October 1979, otherwise a still better yield would have been possible if the experiments with facilities had continued for some more months. Although the survival rate of prawn was poor, the increased production was due to the high rate of stocking. More over the rate of growth was better (10.2 mm/m) in the third experiment (Table 2). Among the three species cultured, the production of *M. cephalus* appeared to be good. Although the growth rate was better in *C. chanos*, gain in weight and rate of survival was better in *M. cephalus* and so a high production from 295-532 kg/ha was obtained.

TABLE 4. *Results of polyculture experiments carried out at Veppalodai Fish Farm during 1977-79*

No. of experiment	Species	Period of culture	Seeds stocked: Number and weight (kg)	Seeds stocked: Size range & mode (mm)	Seeds stocked: Average length (mm) & wt (g)	Harvested fishes: Number and weight (kg)	Harvested fishes: Size range & mode (mm)	Harvested fishes: Average length (mm) & wt (g)	Survival rate %	Production rate/kg/ha year	Total (kg)
	P. indicus	March 77-Dec. 77 (9 months)	4186 7.110	41-91 70-74	70 1.66	936 14.8	96-171 131-140	130 15.8	22.4	70.4	
1.	*M. cephalus*	May 77-Dec. 77 (7 months)	1395 1.325	30-49 35-39	46 0.95	357 48.2	164-300 241-250	226.9 135	25.6	295	498.9
	C. chanos	May 77-Dec. 77 (7 months)	1395 1.222	32-67 45-49	47 0.88	113 21.8	215-370 301-310	277 193	8.1	133.5	
	P. indicus	April 78-Mar. 79 (12 months)	12096 11	40-60 50	51 0.9	979 19.5	135-187 150-165	160 20	8.1	69.6	
2.	*M. cephalus*	May 78-March 79 (9 months)	2062 1.3	22-55 35-45	40 0.8	402 84.4	297-331 310-325	314 210	19.5	361.8	545.7
	C. chanos	April 78-Mar. 79 (12 months)	200 0.160	40-45 40-45	42 0.8	119 32	324-400 340-350	346 268	59.7	114.3	
	P. indicus	May 79-Dec. 79 (6½ months)	21387 19.2	52-64 53.63	58 0.9	1985 28.2	108-171 115-130	126 14.2	9·3	185.9	
3.	*M. cephalus*	April 79-Dec. 79 (7½ months)	680 1.360	60-75 65-70	69 0.2	583 61.8	210-240 220-225	220 106	85.7	353.1	731.0
	C. chanos	April 79-Dec. 79 (7½ months)	980 0.262	27-32 27-32	29 0.142	493 33.6	190-248 210-220	215 68.3	50.3	192	

REMARKS

The problem of maintaining the salinity of the pond water within the favourable range was serious, especially when there was no dependable supply of fresh water to compensate for the high rate of evaporation during the two dry seasons. Juvenile penaeid prawns though euryhaline, would prefer the salinity in the range 10-35‰ and lower or higher salinities retard the growth of the prawns (Muthu, 1978). Suseelan (1976) reported on culture of *P. indicus* in the salt pan reservoirs of Manakkudy were the salinity fluctuated from 4.95 to 28.10‰ with a mean value of 23.22‰ Nair *et al.* (1976) explored the possibilities of culturing *C. chanos* and *P. indicus* in the present environment.

Gopalakrishnan (1970) worked out the salinity tolerance of *M. cephalus* as 0-75‰. Ling (1977) observed the optimum salinity range as 20-30‰ for the culture of milkfish and mentioned about the pumping of fresh water to bring the salinity to the proper level when it reached high levels. In the present experiments, the salinity was well above 36‰ during most of the months and at the time of stocking it was higher still.

In Southeast Asian countries when prawns are stocked with non-predatory fishes in a polyculture system, generally a low rate of stocking between 5,000-10,000/ha of juveniles 2-4 weeks old are used to ensure good survival (Ling 1977). Suseelan (1976) observed a high rate of survival (82%) when stocked with slightly bigger size (68 mm) prawns in ponds. Results of the present experiments also indicated a better survival rate when larger seeds (70 mm) were stocked at lower intensity. Earlier workers have observed a relatively faster growth in the juvenile stages under estuarine conditions only. Subramanyam and Rao (1968) observed a growth rate of 19.35 mm/month for juveniles reared in brackishwater pond near the mouth of Pulicat Lake. Suseelan (1975) recorded 30.5 mm/m in younger stages upto about 125 mm length. In the present observations a maximum of 16.3 mm/m was observed in early stages and the poor growth rate may be attributed to the quality of water.

Tampi (1960) has observed at Mandapam a growth increment of 220 mm by one year in *Chanos* with a survival rate of 9-11 % and production varying between 212 kg-455 kg/ha. Under existing environments at Veppalodai farm the growth appeared to be better *viz.* 304 mm in one year with a survival rate at 59.7%. The production figure of this species in polyculture system cannot be compared with the yield in monoculture experiments. Production would have been considerably more when the stocking intensity is more.

Growth and production of *M. cephalus* has been observed to be different under various environmental conditions. Hora and Pillay (1962) assessed a growth of 140 mm in first year. Jhingran and Natarajan (1969) reported that in Chilka Lake the fish attains an average length of 307 mm in first year. Patnaik (1966) has recorded growth of 325 mm in first year. Considering the high salinity and other environmental characters of the present experiments the growth rate of 274 mm in 9 months for *M. cephalus* appears to be encouraging.

Recent experiments on polyculture of mullet, milkfish and *P. monodon* and milkfish and *P. indicus* at Kakdwip have shown a total production at 1463 kg/ha/7 months and 2196 kg/ha/6 months respectively and relatively low production has been recorded in similar experiments conducted from other centres (Rao, 1978). Results of the present study indicated a steady progress from year to year to a maximum total production of 731 kg/ha/year despite a number of handicaps observed.

CONCLUSIONS AND SUGGESTIONS

Through proper planning and construction of different types of large size ponds and application of sound techniques of management annual production can be increased. Construction of ponds of 2-3 ha near the pump house in a slightly elevated level with provisions for flowing water system would pave way for increasing production in polyculture farming. Duration of the culture period can be altered and an early stocking of prawns around January would appear feasible. Special arrangements during January-February for the supply of fresh water to dilute the sea water of culture ponds from Kallar River may improve the growth of juveniles in the beginning period. The silt loam soil which contains little organic matter and low percentage of clay can be improved by heavy applications of less expensive organic fertilizers such as manure from poultry or other livestock. The use of fertilizers can be experimented without hindrance to the normal production of salt as it would be ideal for the growth of natural food organisms. Such practice is gaining momentum in Southeast Asian countries. Hunting of predatory birds in the area may be permitted for the development of fishing industry as it would minimise the cost on labour.

The success of freshwater aquaculture in Southeast Asia is principally due to the application of polyculture techniques. It should hold good in mariculture also and experiments conducted on the above lines are bound to find solutions to reach better harvest by resorting to polyculture.

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EXPERIMENTAL CULTURE OF PRAWNS AND FISHES IN COASTAL PENS AT TUTICORIN DURING 1976-'78

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ABSTRACT

The paper gives an account of experimental culture of prawns *Penaeus semisulcatus*, *P. indicus* and fishes *Chanos chanos* and *Mugil* in split bamboo screen pens, constructed in the shallow bay at Tuticorin during 1976-'78. The problems encountered in the maintenance of the pens in the locality in the context of tidal conditions, winds and waves, as well as the growth of the culture stocks in relation to the hydro-biological conditions prevailing in the area in the course of the work are recounted. Suggestions for a more effective approach of pen culture in the light of the practical experiences gained in the work are given.

INTRODUCTION

THE PRACTICE of culturing organisms in artificial enclosures implanted at the substratum, called pen culture, appears to have originated in Japan (Felix, 1975) and is in vogue for over fifty years in Cambodia, Thailand and Indonesia, (Devaraj, 1974). Pen culture exercise might have originated in the form of some kind of impoundment of fishes or prawns in artificial enclosures in seas, estuaries, lakes, rivers, and using palisades, hedges of tree branches, split bamboo, as is practiced even today in the Adriatic. However, adequate attention to make use of this method of culture to increase fish production appears to have been bestowed only in recent years including some affluent countries obviously in the wake of increasing demand for seafood (FAO, 1970, 1972 a, b, 1975 ; Devaraj, 1974 ; Felix, 1975 ; Mane, 1975). A distinct advantage with pen culture is that pens could be installed in estuaries, bays, swamps, loches, derelict water masses and coastal areas. And, with the recent advent of synthetic fibres for making durable nets, Synthetic tubes as well as scaffolding frame works for making supporting structures and new formula feeds for sustaining culture stocks, pen culture is assuming increasing importance in different parts of the world (Joyner, 1970; FAO, 1972 b).

In India, with the immense potentialities for coastal aquaculture along the extensive coast of about 6,100 km, dotted with many estuaries, creeks, backwaters, and with the availability of many-a-valuable culturable fish and shellfish, there is great scope for developing pen culture on a viable basis. This becomes much more important while considering the availability of the seeds of culturable marine fishes and prawns (Tampi, 1973) in abundant quantities. Realizing these facts, an experiment on pen culture was taken up at Tuticorin during 1976-78 by the Central Marine Fisheries Research Institute and the experience gained as well as the results obtained therefrom are reported in the present paper, indicating the problems faced and the ways and means of overcoming them.

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Note on Culture Site

The site selected for undertaking the experiment was in Tuticorin Bay, about 2 km south of Tuticorin town and adjoining the mouth of Karapad creek (Fig. 1). The substratum in the site was mostly muddy, becoming sandy towards the shore. Depth of water in the area ranged from 0.75 m to 1.75 m and sinking range of the muddy substratum varied from 25 to 50 cm. Tidal amplitude in the locality fluctuated from 0.75 m to 1.5 m. Patches of sea grasses and small plants were also present in the region.

Atmospheric temperatures in the locality increased from January onwards (23.5°C) reaching the peak during July-September (30.9°C) followed by a declining trend (27.8°C). Sea water temperatures in the pen culture site also registered a similar pattern (24.4, 28.8 and 27°C respectively). Mean values of low tides showed three peaks in an year, one during March-April (83.1 cm), another during August-September (90 cm) and the third during December-January (90.3 cm). On the other hand, mean values of high tides showed only a single peak, usually during April-May (160.8 cm). Rainfall was recorded almost all round the year, although of slight intensities, with the main rainy seasons during April-June and October-December, of which the latter period was more intensive than the former, with peak rainfall of 463.9 mm. Wind velocities usually ranged from low values of 3-13.5 km/h to high values of 37-73.1 km/h. Strong westward winds prevailed from May to middle of September and strong northern or northeastern winds blew from middle of November to April. From September to November, directions of the winds were not constant.

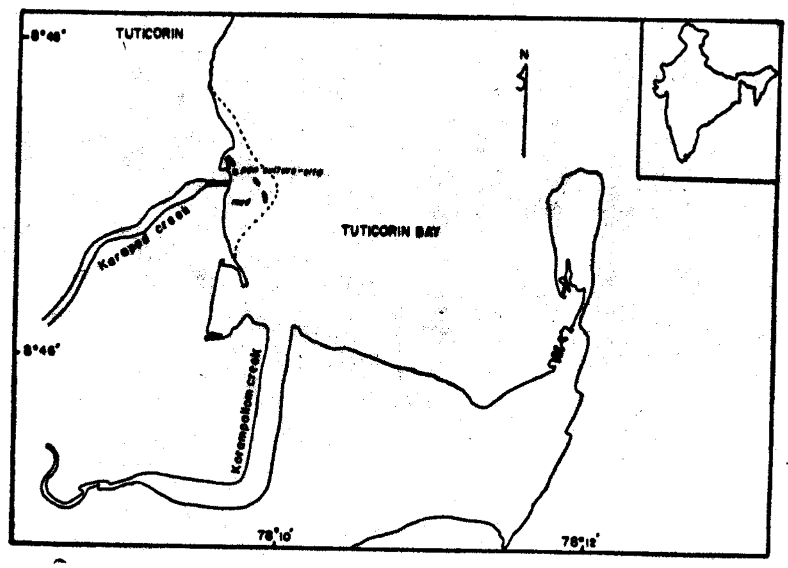

Fig. 1. The pen culture site at Tuticorin.

Hydrobiological Conditions

Salinity values in the culture site during the period 1976-78 ranged from mean figures of 31‰ to 37‰. Lower values were recorded during the months of rainfall and higher values during the summer months (April-June). On rainy days the salinity values became as low as 10-15‰. This was also the case on days when there were influx of fresh water from Karapad creek into the bay. Dissolved oxygen contents in the region varied from 7 to 8 ml/l and pH values fluctuated around 8. One litre samples of sea water collected from the locality and analysed usually contained 1 ml of edible organisms for culture stocks, such as filaments of *Oscillatoria, Pleurosigma, Nitzschia, Navicula,* copepods, nauplii, gastropods and bivalves. Also, epiphytic organisms were found thriving well on the blades of sea grasses and other plants growing in the region. It may be seen from these facts that hydrobiologically the area is quite suitable for the survival and growth of most of the culturable species such as *Chanos, Mugil* and *Penaeus.*

Construction of Pens

Six culture pens were constructed during 1976-78, each of 20m × 10m in extent (Fig. 2). The pens were made up of split bamboo screens, the sticks each measuring about 3 metre long and 20 to 25 mm thickness which were spaced closely together and interwoven with synthetic twines at an interspace of about 30 cm. The screens so made were implanted at the slushy substratum to a depth of about 15 to 30 cm and were supported by vertically planted casuarina or teak wood poles of 3 to 4 m height spaced at a distance of about 3 metres. Horizontal poles of about 3 to 4 m length were fastened to the vertical poles by nails as well as with synthetic ropes, for giving additional

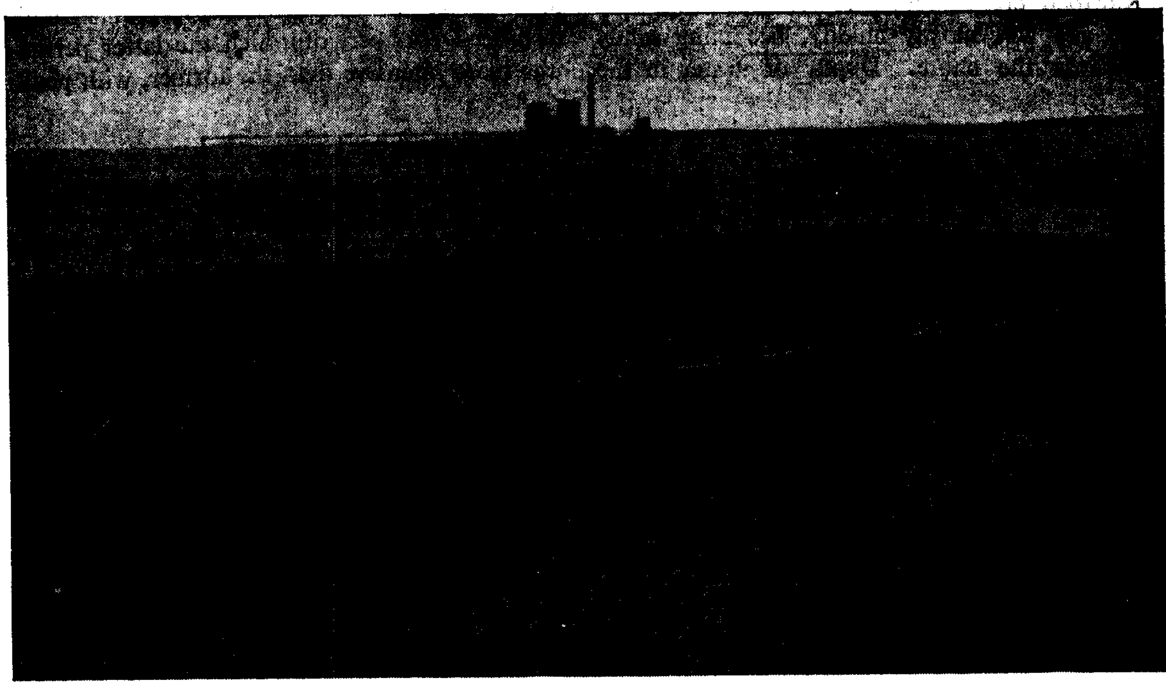

Fig. 2. Coastal pen made up of split bamboo screens with the extent of 20 m × 10 m at Tuticorin.

support to the structure. Obliquely planted props were provided on the outside as well as inside of the pens in order to make them strong enough to withstand the prevailing winds and waves. Within a couple of months of constructing the pens bryozoans, barnacles, algae and oysters were observed to grow on the screens and wooden structures upto a height of about 0.5 to 0.75 m from the bottom, marking the levels usually submerged. Each pen was provided with a small door of about 0.75 × 0.75 m size to facilitate workers and scientists to enter the pens for releasing seeds and taking care of the pens.

RESULTS AND DISCUSSION

The experiments undertaken and results obtained in the six pens are given in Table 1.

The negative results obtained in some of the experiments on the culture of prawns in the pens at Tuticorin appeared to be due to changes in environmental conditions as well as due to damages caused to the pens resulting in the formation of holes serving as passage for prawns to move out. From the condition of the first pen as well as judging the environmental conditions, it appears that the disappearance of *Penaeus semisulcatus* was caused by one or both of the above factors. Due to heavy rains in the months of October (221.6 mm) and November (178.9 mm) 1976 and discharge of large amounts of freshwater from Karapad creek into the bay, the salinity values were brought down to as low as 5-10% in December and January. In May 1977 there was a rainfall of 150.4 mm; and it is possible that a major proportion of the population of *P. indicus* in the second pen might

TABLE 1. *Results of pen culture conducted at Tuticorin during* 1976-78

Pen No.	Species	Rate of stocking (per ha)	Size range (mm)	Av. weight (g)	Size range at harvest (mm)	Av. weight at harvest (g)	Monthly growth rate	
							Length (mm)	weight (g)
1.	*P. semisulcatus** Dec. 76	75,000	35-100	—	—	—	—	—
2.	*P. indicus* Apr. 77-Sep. 77	75,000	35-72	1.30	61-135	4.7	7.0	0.7
3.	*Chanos, Mugil* May 77-Nov. 77	10,000 15,000	23-36 14-33	0.35 0.20	155-225 69-365	41.0 180.0	27.0 23.0	7.0 26.0
4.	*Chanos*	10,000	44.00 (mean)	0.80	301.00 (mean)	240.0	51.00	48.0
	Mugil May 77-Oct. 77	15,000	26.00 (mean)	0.20	169.00 (mean)	90.0	29.00	18.00
5.	*P. indicus* June 77-Apr. 78	75,000	48.79	1.54	46-130	2.6	—	—
6.	*P. indicus* Apr. 78-Sep. 78	75,000	36-75	1.2	51-150	8.2	—	—

* The prawns escaped due to the damage caused to the pen.

have been killed due to this reason. Similarly, in the case of the fifth pen the sudden changes in salinity conditions caused by rains during October (151.8 mm) and November (463. 9 mm) 1977, might have resulted in heavy mortality of *P. indicus*. The small size of prawns harvested in this pen, after a culture period of ten months indicated that the original seeds stocked were completely lost and that the stock harvested belonged to a subsequent stock seeded naturally. In the sixth pen, there was better growth during April-September 1978 period amounting to an average weight increase of 8.2 g. This period was also coincided by scarce rainfall ranging from nil condition in the months of June and August 1978 to 1 mm in May, 1.5 mm in July and 5.5 mm in September. These facts strongly suggest that if natural mortality has taken place on a large scale inside the pens, it might have been caused by sudden changes in salinity conditions.

Another factor which might have contributed to poor growth, survival and production of prawns in coastal pens at Tuticorin appears to be the slushy condition of the substratum. When compared with soil particles in a firm substratum, those in a slushy bottom have the tendency to absorb and fix some of the vital elements in sea water like calcium rather than releasing, resulting in a medium deficient of these vital elements. It is needless to stress that a culture medium deficient in such vital elements as calcium is not at all conducive for the survival and growth of prawns, particularly at the time of their moulting for the formation of shell. It appears quite probable that such deficiencies prevalent in coastal areas where pens are constructed would result in such unsatisfactory growth of prawns as has happened in the sixth pen in which only an average weight increase of 8.2 g was recorded over a culture period of ten months, whereas *P. indicus* is known to register weights upto 15 to 25 g within a culture period of six months in coastal ponds.

As against the poor growth of prawns, *Chanos* and *Mugil* have registered impressive growth increases amounting to 48 g per month for the former and 26 g per month for the latter. The culture medium deficient in vital elements like calcium might not have affected these fishes because their calcium requirements are not so high as the periodically moulting prawns. This clearly indicates that fin-fishes can be cultured with profit and without much difficulty in coastal pens, once the question of affording adequate protection to the stock inside the pens is solved.

The most difficult problem encountered with regard to the present pen culture operations at Tuticorin was the maintenance of the pens for a fairly long period in terms of the investments made and in the context of boring and fouling organisms damaging the split bamboo screens within about three months of their construction. Wood-eating crustaceans, boring molluscs, bryozoans barnacles and oysters have considerably weakened the screens making them highly susceptible for further damage by the prevailing waves, currents and winds. The slow and steady action of waves accompanying the high and low tidal amplitudes has caused wear and tear of the screens already weakened by boring and fouling organisms. These factors were observed to result in the formation of holes particularly at levels at which waves have caused wear and tear of the bamboo. The condition was further aggravated by winds prevailing almost throughout the year. Wind velocities ranging from 45.3 km/h to 73.1 km/h were recorded. The cumulative effect of all these factors was the reason for the brief durability of the pens and their failure to serve as effective structures for culture operations.

It is obvious from the above considerations that for ensuring successful operations, the pens should be constructed in such a way that they are free from the impact of boring and fouling organism. For this purpose, it is essential to treat the materials with anti-fouling agents at least along the portion of the screens that is submerged in water. Alternatively, it is essential to construct coastal pens with galvanized weld mesh or synthetic fibre nets which cannot be damaged by boring and fouling organisms. Synthetic nets made of polyethylene, nylon, kuralon, vinylon, tetron, etc. are useful in this regard (Milne, 1972). In fact, coastal pens in most of the countries including even those in southeast Asian region are constructed with synthetic fibre nets and not with undurable structures like bamboo (Milne, 1972).

While constructing coastal pens, it is essential to do so with strong supports to enable them to withstand strong winds, waves and currents (Milne, 1970). For this purpose, the substratum of the locality selected should be of firm clay or mud so that poles or wooden posts could be driven sufficiently deep inside for affording adequate support to the pen even during rigorous weather conditions. In localities where such net enclosures are likely to be damaged by organisms like crabs, it is desirable to provide an outer predator net covering also. And, in cases where wear and tear of nets are likely to be caused by wave action, a solid barrier consisting of logs of wood may be erected across the way of waves and currents in order to reduce their impact on the pens considerably. It is obvious in this connection that locations such as saline swamps, lagoons, and bays free from strong waves and currents as well as sheltered from rigorous weather conditions are the best locations for resorting to pen culture operations.

Culture of *chanos* in pens in Philippines taken up recently (FAO, 1972 a ; 1975) has proved to be successful and according to Felix (1975), three months old fish have grown to 30-49 cm long, 2 to 3 fishes weighing one kg and after eight months of culture they measured 65-80 cm, each fish weighing 2 to 3.5 kg. Felix (1975) further reports that pen culture of *Chanos* has brought in so much profits that the area of operation was increased from a few ha in 1971 to 7,000 ha in 1974. Mane (1975) states that as much as 10 tonnes of *Chanos* could be produced in one ha. In the present pen culture experiments at Tuticorin, a growth of 48 g per month for *Chanos* and 26 g per month for *Mugil* is recorded, thus pointing out that pen culture operations could be made profitable in India also by paying adequate attention for selection of sites, construction of culture facilities in such a way as to ensure their sound maintenance against winds, waves and currents. There is no dearth of such localities in the coastal regions of India ; and the experience gained in the present experiment points out positively that by utilizing such areas, it is certainly possible to develop pen culture of marine finfishes as a viable industry. Also, by selecting sites with firm substrata suitable for prawn culture operations and by undertaking some soil preparation procedures, it would be possible to develop prawn culture operations also in pens as a profitable venture.

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DISTRIBUTION OF SPECIES OF PRAWNS IN THE BACKWATERS AND ESTUARIES OF INDIA WITH REFERENCE TO COASTAL AQUACULTURE

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ABSTRACT

Several of the species of prawns of marine origin as well as some of the species of freshwater origin have a common brackishwater phase in their life history. As a result of this many of these species occur in large numbers in all the estuaries and backwaters of India in their postlarval and juvenile stages. The distribution of these species in the major brackishwater environments of the country has been studied with reference to their composition and seasonal abundance. The most common species which are suitable for culture purposes are *Penaeus indicus*, *P. monodon*, *P. semisulcatus*, *P. merguiensis*, *Metapenaeus dobsoni*, *M. monoceros*, *M. affinis*, *M. brevicornis* and *Parapenaeopsis sculptilis* among the penaeid prawns and *Macrobrachium rosenbergii*, *M. malcolmsonii*, *M. idella*, *M. equidens*, *M. rude*, *Palaemon styliferus* and *P. tenuipes* among the palaemonid prawns. Although *P. indicus*, one of the species very much in demand for culture, is found in almost all the estuaries, it occurs in maximum abundance in the southwest and southeast coastal regions. *P. monodon*, which grows to the largest size among the penaeid prawns, is most commonly distributed in the estuaries of middle and northern regions of the east coast. *M. dobsoni* is the dominant species in the backwaters of the southwest coast.

In general the postlarval and early juvenile stages of these prawns are encountered almost throughout the year. However, October-May is found to be the peak season of abundance in the brackishwater areas of the west coast and southeast coast, while January-April and August-December are the peak seasons in the estuaries of the middle and northern regions of the east coast. The penetration and spatial distribution of different species in relation to salinity conditions of Vembanad Lake have been traced during their peak season of abundance.

INTRODUCTION

IT IS a matter of common knowledge that most of the commercially important penaeid prawns of marine origin have a brackishwater phase in their life history. Some of the freshwater palaemonid prawns also share the same characteristic of having a brackish water phase. While the former use the estuarine waters as a nursery ground for the young ones after the breeding of the adult in the sea, the latter use these waters for the breeding purposes and early development of the larvae. So the distribution of the various species of prawns in the estuaries and brackish waters becomes important in the context of culture of these species especially with reference to the availability of their young ones to be used for stocking purpose. Information on the distribution of the different species in these environments in some of the estuaries like Cochin Backwaters, Hooghly-Matlah Estuary and others is available in the studies made by Menon and Raman (1961), George (1962 a; 1962 b), Ramamurthy (1963; 1972), Gopalakrishnan (1971), Mohamed and Rao (1971), Rao and Kathirvel (1971), Rajyalakshmi (1972), Sampson Manickam and Sreenivasagam (1972), Evangeline (1975), Rao

(1975), Achuthankutty *et al.* (1977), Deshmukh (1977), Suseelan (1977), Goswami and George (1978) and Suseelan and Kathirvel (1979).

The present contribution deals with the occurrence and distribution of these prawns in all the important estuarine systems of the country. An attempt is also made to trace the penetration and spatial distribution of different species of Vembanad Estuary with special reference to the salinity conditions prevailing in the summer months.

Species Commonly Occurring in the Brackishwater Environments

Sixteen species of prawns belonging to the family Penaeidae, 4 species to Sergestidae and 7 species to Palaemonidae have been found to occur commonly in the various estuarine environments along the coasts. They are listed in Table 1 along with their common English names and the maximum size attained in the natural brackishwater ecosystems.

Among these species, considering the size attained and other biological features adapted to brackishwater habitats 11 species of penaeids namely, *P. indicus*, *P. monodon*, *P. semisulcatus*, *P. penicillatus*, *P. merguiensis*, *M. dobsoni*, *M. monoceros*, *M. affinis*, *M. brevicornis*, *M. kutchensis* and *P. sculptilis* and 7 species of palaemonids, namely, *M. rosenbergii*, *M. malcolmsonii*, *M. idella*, *M. equidens*, *M. rude*, *P. styliferus* and *P. tenuipes* are important from the point of view of large scale culture.

Distribution of Species

The distribution of common species of prawns available in the important brackishwater areas of the maritime states of India is shown in Table 2.

Areawise distribution

In the estuaries and backwaters of Kerala, *M. dobsoni* ('thelli chemmeen') is the most dominant species contributing to the capture as well as the traditional culture fisheries. Other important species are *P. indicus*, *P. semisulcatus*, *M. monoceros*, *M. affinis*, *M. rosenbergii*, *M. idella* and *M. equidens*. While *P. indicus* and *M. monoceros* are available in fair abundance along with *M. dobsoni* in all the brackishwater areas, *P. semisulcatus* is commonly encountered only in Ashtamudi and Cochin Backwaters particularly in the deeper muddy grounds. Early juveniles of *P. indicus* are often met with in enormous numbers in shallow areas near the shore. Many species of prawns are known to utilize Netravathy and Aghanashini Estuaries of Karnataka as their nursery grounds of which *M. dobsoni* is the predominant one. *P. indicus* in the former environment and *P. merguiensis* in the latter are the other two important cultivable species that are available in association with *M. monoceros*. The Zuari and Mandovi Estuaries of Goa harbour several species, the most common being *M. dobsoni*, *M. monoceros*, *P. merguiensis* and *M. rosenbergii*. The brackishwater creeks of Maharashtra and Gujarat are more or less similar in regard to the occurrence and composition of prawn species. Most of the species available in the coastal waters are drawn into these environments along with tide. *M. monoceros* in Maharashtra and *M. kutchensis* in the Kutch region of Gujarat are the most important species. Other species of common occurrence are *P. merguiensis*, *P. penicillatus* and *P. sculptilis* among penaeids and *P. tenuipes* among non-penaeids. The estuaries of Tapti and Narmada rivers are good breeding grounds for *M. rosenbergii*.

The east coast, in general, is richer in having more number of estuaries than the west coast and all of them are excellent nursery areas for many species of prawns. Invariably in all

TABLE 1. *Species of prawns commonly occurring in the brackishwater environments of India*

Name of species	Common name	Maximum size (mm) attained in estuaries and backwaters
FAMILY PENAEIDAE		
Penaeus indicus H. Milne Edwards	Indian white prawn	160
P. monodon Fabricius	Jumbo tiger prawn	230
P. semisulcatus de Haan	Green tiger prawn	150
P. merguiensis de Man	Banana prawn	160
P. penicillatus Alcock	White prawn	150
P. latisulcatus Kishinouye	Brown prawn	100
P. canaliculatus (Olivier)	Striped prawn	100
Metapenaeus monoceros (Fabricius)	Speckled prawn	100
M. affinis (H. Milne-Edwards)	Jinga prawn	80
M. dobsoni (Miers)	Flower tail prawn	90
M. brevicornis (H. Milne-Edwards)	Yellow prawn	100
M. burkenroadi Kubo	Green tail prawn	90
M. kutchensis George, George & Rao	Ginger prawn	100
Parapenaeopsis sculptilis (Heller)	Rainbow prawn	110
P. hardwickii (Miers)	Spear prawn	120
P. stylifera (H. Milne-Edwards)	Kiddi prawn	100
FAMILY SERGESTIDAE		
Acetes indicus H. Milne-Edwards	Jawla paste shrimp	40
A. erythraeus Nobili	Tsivakihini paste shrimp	35
A. sibogae sibogalis Achuthankutty & George	—	30
A. cochinensis Rao	—	20
FAMILY PALAEMONIDAE		
Macrobrachium rosenbergii (de Man)	Giant river prawn	320
M. malcolmsonii (H. Milne-Edwards)	Monsoon river prawn	230
M. idella (Hilgendorf)	Slender river prawn	120
M. equidens (Dana)	Rough river prawn	100
M. rude (Heller)	Hairy river prawn	130
Palaemon styliferus H. Milne-Edwards	Roshna prawn	90
P. tenuipes (Henderson)	Spider prawn	80

TABLE 2. *Distribution of species of prawns in the brackishwater environments of the maritime States of India*

Maritime States	Environment	Common species of prawns	Period of occurrence	Peak period of abundance
KERALA	Ashtamudi Lake	*Metapenaeus dobsoni*	Throughout the year	October-May
		Penaeus semisulcatus	September-May	November-April
		P. indicus	Throughout the year	October-May
		P. latisulcatus	October-May	November-April
		M. monoceros	Throughout the year	October-April
		Acetes erythraeus	Occasional	December-April
		Macrobrachium idella	Throughout the year	June-August

TABLE 2 (*Contd.*)

Maritime States	Environment	Common species of prawns	Period of occurrence	Peak period of abundance
	Cochin Backwaters	*M. dobsoni*	Throughout the year	August-January
		P. indicus	-do-	December-May
		M. monoceros	-do-	February- May & August-November
		P. semisulcatus	December-June	January-March
		M. affinis	Throughout the year	March-August
		P. monodon	Occasional	March-May
		P. canaliculatus	December-May	March-May
		Parapenaeopsis stylifera	February-May	March-May
		Acetes indicus	Occasional	December-May
		A. erythraeus	Occasional	December-May
		M. idella	Throughout the year	June-October
		M. rosenbergii	Occasional	June-October
		M. rude	Occasional	June-October
		M. equidens	Occasional	June-October
	Korapuzha Estuary	*M. dobsoni*	Throughout the year	December-May
		M. monoceros	-do-	December-April
		P. indicus	November-August	April-May
		P. monodon	Occasional	—
		P. stylifera	Occasional	March-May
		A. indicus	Occasional	March-May
KARNATAKA	Nethravathy Estuary	*M. dobsoni*	Throughout the year	October-November
		P. indicus	Throughout the year	January-March
		M. monoceros	Throughout the year	February & October-November
		P. merguiensis	Throughout the year	January-February
		P. monodon	Occasional	—
		M. affinis	Occasional	—
	Aghanashini Estuary	*M. monoceros*	Throughout the year	October-January
		M. dobsoni	Throughout the year	November-March
		P. merguiensis	Throughout the year	December-February
GOA	Zuari Estuary	*M. dobsoni*	Throughout the year	January-April
		M. monoceros	Occasional	January-April
		P. indicus	October-June	February-May
		P. merguiensis	Occasional	January-May
		P. stylifera	Occasional	February-May
		M. rosenbergii	Occasional	May-September
	Mandovi Estuary	*M. dobsoni*	Throughout the year	July & January-March
		M. Monoceros	Occasional	January-March
		P. merguiensis	Occasional	January-May
		P. stylifera	Occasional	March-May
		M. rosenbergii	Occasional	May-September
MAHARASHTRA	Creeks of Bombay area	*M. monoceros*	Throughout the year	February-April & October-December
		P. merguiensis	Occasional	December-May

TABLE 2 (*Contd.*)

Maritime States	Environment	Common species of prawns	Period of occurrence	Peak period of abundance
		P. penicillatus	Occasional	October-December
		M. affinis	Occasional	—
		M. brevicornis	Occasional	—
		A. indicus	Occasional	
		Palaemon tenuipes	Occasional	April-May
		P. styliferus	Occasional	—
		Parapenaeopsis hardwickii	Occasional	—
		P. sculptilis	Occasional	June-September
GUJARAT	Narmada & Tapti Estuaries	*M. monoceros*	Throughout the year	October-November
		P. sculptilis	Throughout the year	June-September
		P. tenuipes	Occasional	—
		P. penicillatus	Occasional	—
		M. rosenbergii	Occasional	May-October
	Rann of Kutch and creeks	*M. kutchensis*	July-October	August-October
		P. merguiensis	Occasional	January-May
		M. brevicornis	Occasional	January-May
		M. monoceros	Occasional	—
		P. penicillatus	Occasional	—
		P. tenuipes	Occasional	—
TAMIL NADU	Manakkudy Estuary	*P. indicus*	Throughout the year	February-April & June-July
		M. dobsoni	Throughout the year	February-March & September-November
		M. monoceros	Throughout the year	February-May & September-November
		P. monodon	Throughout the year	April & September-November
	Malattar Estuary	*P. indicus*	Throughout the year	—
		M. monoceros	Throughout the year	—
		M. affinis	Throughout the year	—
	Killai backwaters	*P. indicus*	Throughout the year	November-March
		M. monoceros	Throughout the year	October-December
		M. dobsoni	Throughout the year	October-December
		P. monodon	Throughout the year	November-December
		M. rosenbergii	August-March	October-December
	Kovelong Backwater	*P. indicus*	Throughout the year	December-March
		M. monoceros	Throughout the year	July-November
		M. dobsoni	Throughout the year	June-November
		P. monodon	Throughout the year	December-March
	Pulicat Lake	*P. indicus*	Throughout the year	March-April & October-November
		M. monoceros	Throughout the year	—
		P. monodon	Throughout the year	—
		P. semisulcatus	Occasional	—
		M. dobsoni	Occasional	—
		P. canaliculatus	Occasional	—

TABLE 2 (*Contd.*)

Maritime States	Environment	Common species of prawns	Period of occurrence	Peak period of abundance
ANDHRA PRADESH	Godavari Estuary	*M. monoceros*	Throughout the year	October-December
		M. dobsoni	Throughout the year	October-December
		P. indicus	Throughout the year	February-April & October-December
		P. monodon	-do-	October-February
		M. brevicornis	-do-	March-May & November-December
		M. affinis	-do-	July-September
		P. merguiensis	-do-	October-December
		A. indicus	Occasional	—
		P. tenuipes	July-November	July-October
		M. malcolmsonii	Occasional	August-November
		M. rosenbergii	Occasional	August-October
		M. rude	Occasional	August-November
	Konada Estuary	*M. monoceros*	Throughout the year	August-October
		M. dobsoni	-do-	September-October
		P. indicus	-do-	May-June & August-September
		P. monodon	Occasional	—
ORISSA	Chilka Lake	*P. indicus*	Throughout the year	February-April & July-October
		P. monodon	-do-	March-September
		P. semisulcatus	-do-	January-April & June-October
		M. monoceros	-do-	March-April & July-October
		M. dobsoni	Occasional	—
		M. affinis	Occasional	—
		M. rosenbergii	Occasional	—
		M. rude	Occasional	—
		M. malcolmsonii	Occasional	—
WEST BENGAL	Hooghly Matlah Estuarine system	*M. brevicornis*	Throughout the year	July & October-December
		P. styliferus	August-January	September-December
		P. sculptilis	February-December	February-June
		P. tenuipes	Occasional	October-December
		P. indicus	Throughout the year	January-April & August-September
		P. monodon	Throughout the year	February-May & August-September
		P. semisulcatus	Occasional	—
		P. canaliculatus	Occasional	—
		M. monoceros	Occasional	—
		A. indicus	Occasional	—
		M. affinis	Occasional	—
		M. rosenbergii	Occasional	July-October
		M. malcolmsonii	Occasional	July-October
		M. rude	Occasional	July-October
		P. stylifera	Occasional	March-May

the major brackishwater environments of Tamil Nadu like Killai Backwaters, Kovelong Backwaters and Pulicat Lake, including the Manakkudy Estuary situated on the extreme southwest coast, *P. indicus* is the principal species which some times forms more than 90% of the commercial catches. Other species of importance are *M. dobsoni*, *M. monoceros*, *P. monodon* and *M. rosenbergii*. The Godavary Estuary in the south and Konada Estuary in the north of Andhra Pradesh Coast are mostly inhabited by *M. monoceros*, in close association with *M. dobsoni* and *P. monodon*, in all gradients of salinity. *P. indicus* and *M. brevicornis* also occur in appreciable quantities in the lower estuary and *M. rosenbergii* and *M. malcolmsonii* in the upper reaches. The northernmost region of this coast bordering Orissa and West Bengal has the maximum number of estuaries in the country and they harbour large varieties of species both endemic as well as immigrants. The prawn fauna of Chilka Lake is chiefly represented by *P. indicus*, *P. monodon* and *M. monoceros* which are highly suitable for culture. Good concentrations of these species are known to exist in the central and northern sections of this environment. The Hooghly-Matlah estuarine complex of West Bengal, with its vast mangrove swamps and net work of rivers, supports abundant resources of penaeid as well as palaemonid prawns. While the marine zone of this ecosystem is mainly occupied by stenohaline species like *M. brevicornis*, *P. sculptilis* and *P. styliferus*, the middle and upper zones serve as good nurseries for more euryhaline penaeids like *P. monodon* and *P. indicus* and a few of the cultivable carideans like *M. rosenbergii*, *M. malcolmsonii* and *M. rude*.

Seasonal Distribution and Abundance

Since prawns are continuous breeders their postlarvae and young ones are encountered in estuarine areas throughout the year with peak seasons of abundance. Considerable variations exist among species as to their peak period of abundance which coincide with their peak breeding seasons. In the case of seasonal estuaries the opening and closing of bar mouth affect the postlarval ingress into nursery grounds and eventually result in wide fluctuations in their abundance. Salinity and other environmental parameters also play important roles in limiting the distribution of species in time and space.

It is evident from Table 2 that, in the case of penaeid prawns, October-May is the peak season of occurrence for most of the species in the brackishwater areas of the west coast and southeast coast. In the creeks of Kutch, however, the maximum abundance of *M. kutchensis* is recorded during the monsoon period of August-October (Ramamurthy, 1963). On the middle and northern regions of east coast, two peaks — one in January-April and the other in August-December are common to majority of the species. Among palaemonid prawns the marine species *P. tenuipes* and *P. styliferus* ascend creeks and estuaries in abundance during April-May in the northwest coast and September-December in West Bengal. Those species belonging to the genus *Macrobrachium* migrate from rivers to low saline habitats for breeding and occur in large numbers in estuarine areas during the monsoon period.

Occurrence and Spacial Distribution of Penaeid Prawns in Vembanad Estuary in Relation to Salinity

It is noticed that the penetration of the different species of penaeid prawns into the interior parts of the brackishwater areas is dependent to a certain extent on salinity. In order to understand the nature of this penetration of these species into the brackishwaters the Vembanad Estuary was selected to make a detailed study. The extensive backwaters connected with this estuary is important from the point of view of occurrence of large quantities of juveniles of cultivable species of prawns and possibility of collection of these juveniles for stocking and culturing. Therefore the study would also elucidate the extent of availability of these juveniles towards the interior of the estuarine area.

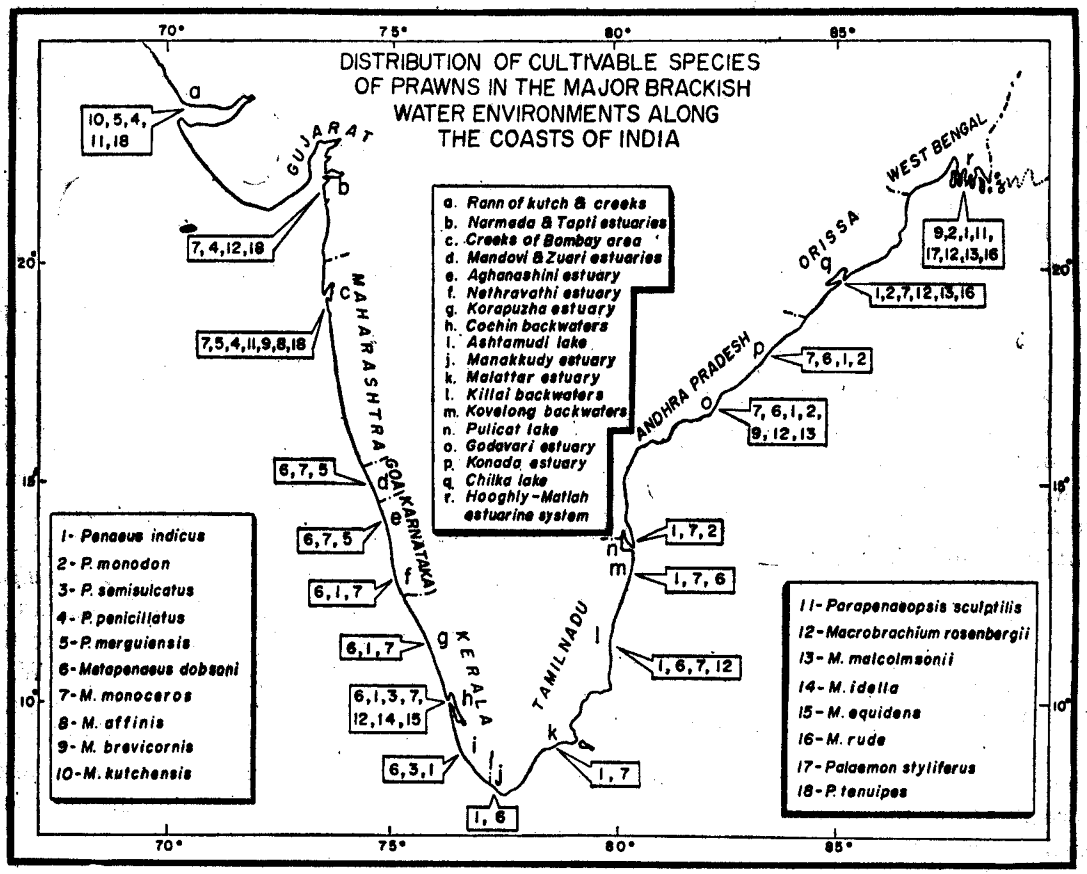

Fig. 1. Distribution and relative abundance of cultivable species of prawns in the different estuarine systems along the coast of India.

Regular monitoring studies on the recruitment of these prawns into these backwaters have been carried out at fixed stations for the past several years. Analysis of the data on the occurrence of different species in relationship with the salinity of the area based on the year round studies indicates that different species have different levels of penetration into the saline areas of the estuary.

It can be seen from Fig. 2 that among the eight species of penaeid prawns commonly occurring in this environment *P. indicus*, *P. monodon*, *M. dobsoni* and *M. monoceros* are the most tolerant to low salinity conditions thriving well in salinities below 5‰. Species such as *P. semisulcatus*, *P. canaliculatus* and *M. affinis* are relatively less euryhaline in nature and they penetrate into areas of moderate salinities. The occurrence of *P. stylifera* is very much restricted to high saline conditions, the minimum salinity at which it was recorded being 25.32‰.

In the Vembanad Estuary a series of sampling by experimental fishing was conducted between Ernakulam Channel at the mouth of the estuary and Pathiramanal about 55 km south during the peak summer period (February-April) of

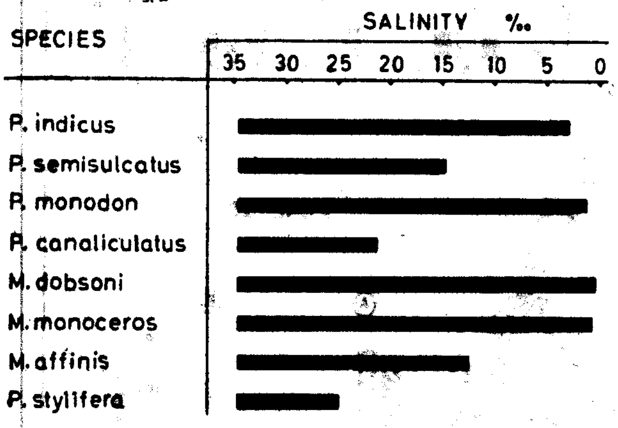

Fig. 2. Penetration of penaeid prawns into the Vembanad Estuary in relation to salinity.

1977-79, when the salinity was at its maximum throughout this environment. Prawn samples were collected from near the shore by operating a velon screen drag net of 2 × 1 metre size having 49 meshes/cm², and from the deeper region by a specially designed try-net (small trawl net) measuring 4 metres in overall length, 5.4 m head rope, 5.4 m foot rope, with mesh size of 8 mm throughout. At each sampling the drag net was operated for two minutes in shallow areas near the shore and the try-net for 10 minutes in the middle channel during the forenoon period. Salinity of the water from where prawn samples were collected was also recorded at each time of observation. Altogether 21 drag net hauls at 6 stations namely Ramanthuruth (8), Panavalli (3), Anchuthurthu (4), Pallippuram (2), Thanneermukkom (1) and Kaippuram (3) and 30 trynet hauls at 3 stations, namely Thevara (8), Vaikom (12) and Pathiramanal (10) were taken during this investigation (Fig. 3).

The salinity showed a gradual declining pattern towards south upto Thanneermukkom bund and thereafter suddenly dropped to almost nil. Based on the different salinity conditions observed at the sampling stations, the estuary is divided into the following three topographical zones:

Zone I. Cochin Barmouth to Kumbalam south. This zone can be termed as the marine zone which is characterised by higher salinities ranging from 22.4‰ to 34.5‰.

Zone II. Kumbalam south to Thanneermukkom bund. This is the gradient zone where the salinity is quite unstable and shows progressive decline from 21.9‰ at north to 9.3‰ at south.

Zone III. Thanneermukkom bund to Pathiramanal. This upper zone is nearly fresh water in character with salinities ranging between 0.6‰ and 2.6‰.

Eight species of penaeid prawns namely *P. indicus, P. semisulcatus, P. monodon, P. canaliculatus, M. dobsoni, M. monoceros, M. affinis and P. stylifera* were recorded during this survey and their postlarvae and juveniles were collected in varying degrees of abundance. The occurrence and relative abundance of the prawns in the three zones are shown in Fig. 3. It is evident that in Zone I all the eight species are represented, with *P. indicus* as dominant species near the shore and *M. dobsoni* in the deeper areas. The species recorded from Zone II included *P. indicus, M. dobsoni, M. monoceros* and *M. affinis,* of which the first two species were the most common. Although distributed throughout this zone, the abundance of *P. indicus* in the near-shore areas was relatively of a

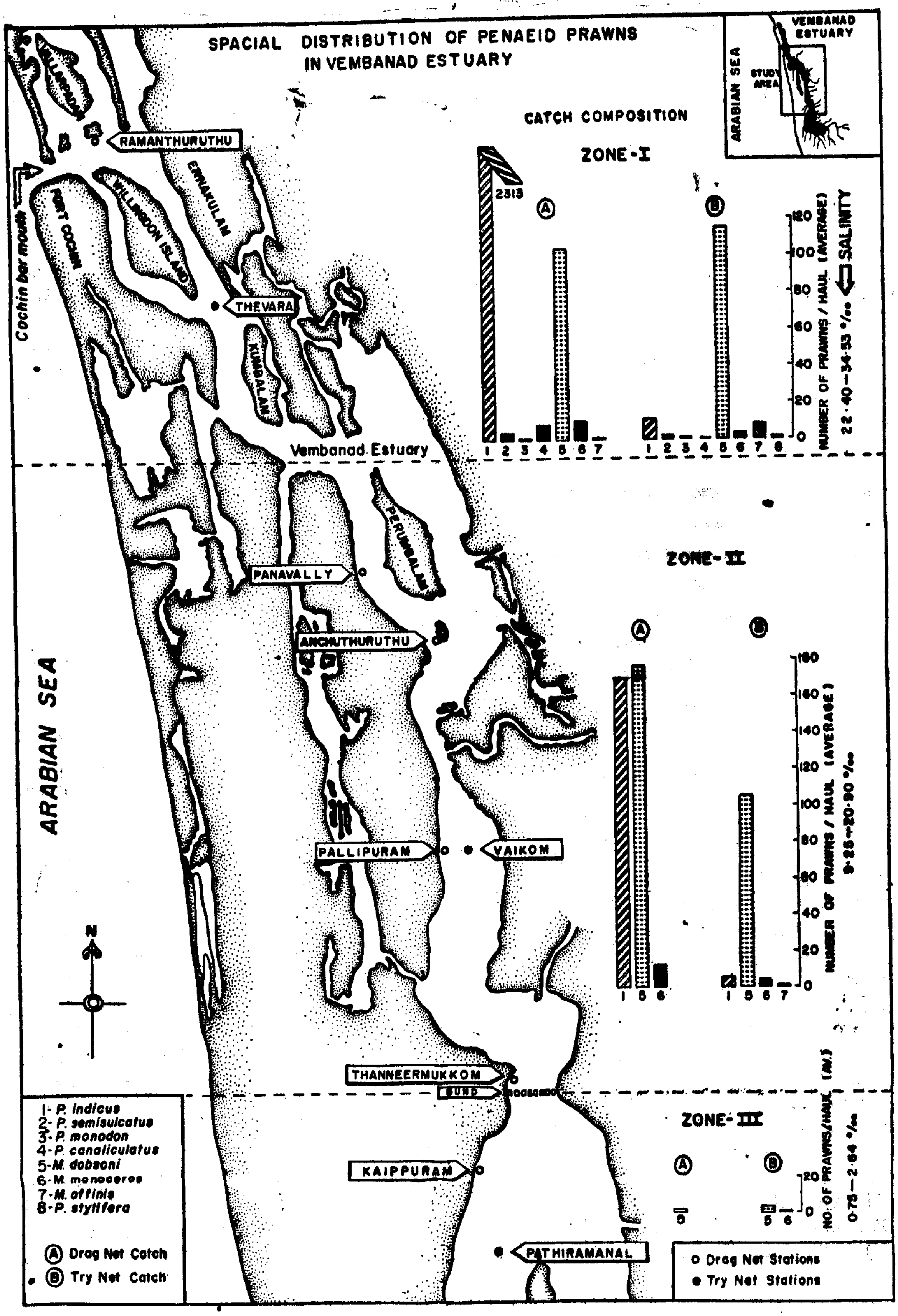

Fig. 3. Spacial distribution of penaeid prawns in the Vembanad Estuary.

lesser magnitude when compared to that of the previous zone. *M. dobsoni* out-numbered *P. indicus* at most of the stations of this zone, while *M. affinis* was only rarely encountered in the try net collections. In Zone III, penaeid prawns were extremely rare. Here, *P. indicus* and the other related species were totally absent. *M. dobsoni* and *M. monoceros*, however, were seen to survive in this part of the estuary on account of their ability to survive very low salinity conditions.

Conclusion

In general, from the distribution, pattern and occurrence of different species in the various estuaries and backwaters along the coast of India it would appear that the juveniles of *Penaeus indicus*, the Indian white prawn which is in great demand from the industry is the most common in most of the estuaries of the east and southwest coasts. *Metapenaeus dobsoni*, the species, which is quantitatively the most important, is dominant in the estuaries of the middle and southern regions of both east and west coasts. *Metapenaeus monoceros* is one of the species which is invariably found in all the estuaries although not in very large quantities. From the point of view of culture *P. indicus* seems to be the most suitable species, particularly in the southwest coast.

Although the postlarval and early juvenile stages of most of the important penaeid prawns occur throughout the year in these brackishwater areas, peak seasons are observed. While October-May appears to be the peak season of their occurrence in the brackishwater areas of the west and southeast coasts, October-December is the main season in the estuaries of the middle and northern regions of the east coast.

Study on the occurrence of the different species in different zones of the Vembanad Estuary in relationship to salinity indicates the tolerance of the species to lower salinities. Only two species namely *M. dobsoni* and *M. monoceros* are encountered in the zone of very low salinity. *P. indicus* also penetrates to very low salinity areas but only upto zone II. With reference to culture of these prawns this is of considerable significance since the availability of seeds in sufficient quantities is an important criterion in the selection of sites for culture activities.

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BRACKISHWATER PRAWN FARMING IN THE ASHTAMUDI LAKE AREA (S. W. COAST OF INDIA)—ITS PROSPECTS AND PROBLEMS

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Abstract

In the Ashtamudi Lake area (Quilon Dist., Kerala) where scientific aquaculture practices of any kind were not in existence, the CMFRI initiated a demonstration project for the culture of marine prawns in 1978. Fourteen ponds having a total extent of 2.06 ha, owned by M/s. Blackstone Industries at Neendakara were selected for the above purpose.

Pre-stocking observations on bio-ecological parameters were carried out which indicated that the ponds were highly productive and provided optimum conditions for culture operations. Early juveniles of *Penaeus indicus* of 15-25 mm (18.2 mm mean length) size groups were stocked during June-July 1978 at a rate of 50,000 to 70,000/ha. During the pre-monsoon period of 1979 (January to June) the stocking rate of *P. indicus* seeds (mean length 18.0 mm) varied from 56,000 to 252,000/ha. The average growth per day was found to be 0.73 mm and 0.54 mm respectively in the culture experiments of 1978 and 1979. The difference observed in the growth rate was mainly due to the increase in stocking density in 1979. However, growth rate of the species during the first 20 days after stocking was consistently faster in both the years, average being 1.86 mm/day in spite of varying environmental conditions and stocking density.

The feed back data collected during the demonstration experiments provided baseline information for the introduction of scientific farming of penaeid shrimps in this area.

Introduction

In recent years, the prospect of aquaculture has been gaining wide recognition throughout the country. However, it is yet to become popular as a profession or occupation for the farmers in view of the paucity of information on the economic viability and financial dependability. In order to fill up this lacuna, the Central Marine Fisheries Research Institute has taken up demonstration projects in aquaculture in several parts of the country.

Convinced of the potentialities of areas of unused marshy lands available on both sides of the lower reaches of the Ashtamudi Lake in the Quilon district, Kerala, and in view of the meagre developments made in aquaculture in this coastal area, a project was undertaken from 1978 as a pioneering attempt for the cultivation of prawns in a perennial field owned by a private entrepreneur. The present paper deals with the culture operations carried out in two seasons and the results obtained therefrom under the project.

The authors are grateful to Dr. E. G. Silas, Director, Central Marine Fisheries Research Institute, who identified the farm and gave all encouragements in carrying out the experiments. They are also thankful to the Proprietor and staff of Quilon Dairy, Neendakara for their active co-operation. The authors wish to record their sincere thanks to Dr. P. Vedavyasa Rao, Senior Scientist for critically going through the manuscript and suggesting improvements.

ENVIRONMENT

Topography

The farm, where the operation was undertaken, is in Neendakara, a major fishing port of Kerala and is about 160 km south of Cochin.

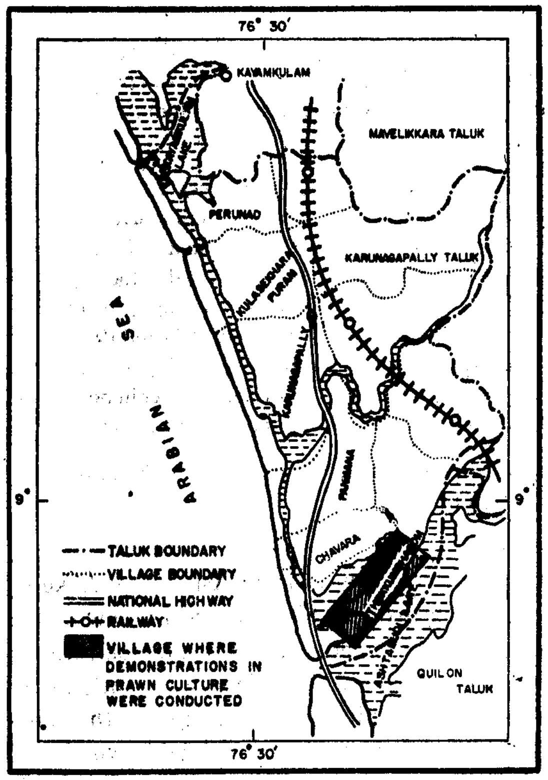

Fig. 1. Area of operation at Quilon District.

The area is situated on the banks of the estuary formed by the lower reaches of the Ashtamudi Lake and has a net work of canals and subcanals and is greatly influenced by the tidal flow (Fig. 1).

Studies on prawn culture were conducted in 14 ponds having a total area of 2.06 ha owned by M/s Blackstone Industries, Trivandrum. The lay out of the farm and the extent of each pond are shown in Fig. 2. The farm is supplied with water from a feeder canal of about 6 m wide and 500 m long which has a direct connection with the lake. There is a main wooden sluice of one metre width, and it opens into the pond N (Fig. 2). From pond N, the water is supplied to all other ponds through interconnections protected with velon screens. The depth of each pond varied, and at low tide the average depth ranged between 0.55 and 1.0 m (Fig. 2).

Pre-farming environmental conditions

Two sets of prawn culture operations were carried out, one during the south-west monsoon period of 1978 (July-October) and the other during the pre-monsoon period of 1979 (January-June). In order to ascertain the viability of conducting prawn culture in the farm, prestocking monitoring of the environmental and biological parameters, such as temperature, salinity, dissolved oxygen, pH, primary and secondary production was conducted in May and June 1978. The results of the initial observations are presented in Table 1.

The surface temperature of the pond waters was found to range between 29.5 and 34.0°C and rose upto 35°C in one pond. There were wide variations in salinity which fluctuated between 0.09‰ in pond H and 18.54‰ in pond C. The dissolved oxygen values were always high and in pond D it went upto 7.06 ml/l. The pH values in most of the ponds were around 7. The primary productivity estimated by both oxygen and ^{14}C methods showed wide range of fluctuations in the rate of production in the different ponds. The results indicated that ponds B, C, F, G, I and K had high rates of production. Common forms of phytoplankters were desmids like

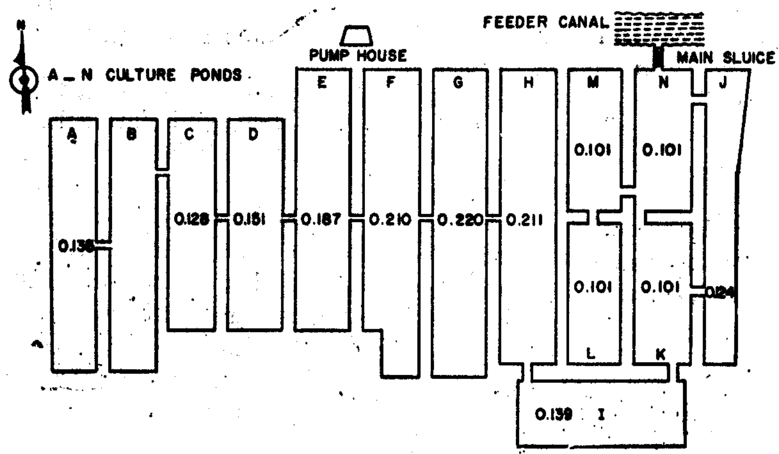

Fig. 2. Lay out of the farm where demonstration operations were conducted. Area of each pond (ha) is indicated.

TABLE 1. *Results of pre-stocking monitoring of environmental parameters in May* 1978

Ponds	Months and year	Average depth at low tide (m)	Temperature °C	Salinity ‰	Oxygen ml/1	pH	Organic Production gC/m³/day	Zoo-plankton biomass ml/100 1 of water
A	May 1978	0.77	32.5	9.26	3.93	7.0	—	2.4
B	,,	0.70	32.0	16.72	3.20	7.16	1.93	2.9
C	,,	0.92	32.0	18.54	5.33	7.63	5.42	10.5
D	,,	0.95	32.0	17.90	7.06	7.69	—	—
E	,,	0.85	32.5	4.81	3.09	7.47	0.92	2.9
F	,,	0.85	32.5	18.45	3.70	7.47	1.24	—
G	,,	0.57	34.0	17.99	6.90	8.12	1.37	7.7
H	,,	0.55	35.5	0.09	4.47	7.08	0.86	—
I	June 1978	1.00	29.5	11.57	5.26	—	1.01	0.65
J	,,	0.80	30.0	10.03	6.75	—	—	1.20
K	,,	0.85	31.0	4.52	5.68	—	1.91	2.20

Euastrum, *Cosmarium* and *Desmidium* species and the micro-green algae and diatoms such as *Coscinodiscus*, *Pleurosigma* and *Rhizosolenia*. In general, the production at the secondary level was found to be high in all the ponds (the highest value of biomass (10.5 ml/100 l of water) was recorded in pond C). On the whole the adults and larvae of copepods dominated the zooplankton samples followed by rotifers, foraminifers, larvae of nematodes, bivalves and crustaceans.

Stocking

The ponds were cleared of predators and other fishes by total fishing and by pumping out the water completely. Thereafter the water was allowed into the ponds through the nylon netting provided at the sluice gate. After filling with water, the ponds were left free for 2 to 3 days and after which they were stocked with seeds of *P. indicus*. At no stage of the culture operations the tidal waters were controlled unless some adverse blooms were seen in the lake waters.

The seeds of *P. indicus* required for stocking were collected from the Ashtamudi Lake from the nearby areas of the farm. The seeds were collected using a velon screen of 1.5 × 1.0 m which was manually operated by two persons by slowly dragging close to the bottom for short distances. The net was operated in shallow muddy areas from the very water fringe upto 0.5 m depth. The collections were carried out usually at the beginning of the high tide or towards the last phase of the ebb tide. Schools of *P. indicus* seeds were often observed in these grounds and in a single operation which covered about 6 m^2 more than 5,000 seeds were obtained. The seeds were transported from the collection site to the farm in plastic bins of 60 litre capacity. From the general collections the healthy ones of *P. indicus* of almost uniform size were sorted out, counted and released into the ponds after a brief acclimatization in the pond water.

The details of stocking of *P. indicus* seeds in the different ponds during the culture operations carried out in 1978 and 1979 are given in Table 2. The stocking rate varied from about 50,000 to 70,000/ha in 1978. However, in the experiments conducted in 1979, the stocking rate was relatively high, being about 56,000 to 252,000/ha. After stocking, the environmental parameters were monitored every fortnight. Along with this the growth rate of prawns was also checked. No supplementary feed was given during both the experiments.

Growth pattern of Prawns

For studying the growth of *P. indicus* in the grow out ponds, data were regularly collected and analysed from ponds A, I, J, K in 1978 and from ponds I, J, K and N in 1979. The size range of the seeds and mean size stocked in the first three ponds in 1978 were 15-25 mm and 18.2 mm respectively. In pond K, the seeds with a size range of 20-46 mm and with a mean size of 31.2 mm were stocked. In 1979, the mean size of the seeds stocked in all the ponds was 18.9 mm. The rate of growth of prawns in the different ponds during the culture experiments of 1978 and 1979 are given in Figs. 3 and 4.

The rate of growth of prawns in the culture experiments of 1978 in the different ponds varied from 0.60 mm/day in pond A to 0.86 mm/day in pond J. However, relatively low growth rate (0.42 mm/day in pond K to 0.63 mm/day in pond I) was observed in the experiments carried out in 1979. The average growth per day was found to be 0.73 mm and 0.54 mm respectively in the culture experiments of 1978 and 1979. The difference observed in the growth rate was mainly due to the increased rate of stocking of seeds in 1979.

TABLE 2. *Details of stocking of* P. indicus *seeds in the ponds* (*A-N*) *in* 1978 *and* 1979

Ponds	Area in ha.	1978 Date of stocking	1978 No. of seeds stocked	1978 Estimated rate of stocking per ha.	1979 Date of stocking	1979 No. of seeds stocked	1979 Estimated rate of stocking per ha.
A*	0.153	26.6.78	10,726	70,105	—	—	—
B	0.153	5.8.78	8,200	53,595	—	—	—
C	0.128	10.8.78	7,400	57,813	20.2.79	11,000	85,938
D	0.151	11.8.78	7,525	49,834	10.2.79	21,500	142,384
E	0.187	3.9.78	9,700	51,872	20.2.79	22,000	117,647
F	0.210	3.9.78	11,840	56,381	13.2.79	12,800	60,952
G	0.220	20.8.78	11,050	50,227	7.2.79	12,800	58,182
H	0.220	16.8.78	11,450	52,045	6.2.79	12,300	55,909
I*+	0.139	21.6.78	7,393	53,187	29.1.79	17,100	123,022
J*+	0.124	7.7.78	6,359	51,282	28.1.79	11,100	89,516
K*+	0.101	7.7.78	5,050	50,000	1.2.79	12,100	110,802
L	0.101	14.8.78	5,650	55,941	5.2.79	11,000	108,912
M	0.101	20.8.78	5,150	50,990	15.2.79	25,500	252,475
N+	0.101	8.8.78	5,050	50,000	25.1.79	10,300	101,980

* Ponds monitored regularly for the study of growth pattern in 1978.

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Lowering of salinity from the maximum of 13.29‰ in June to 4.45‰ in September was noticed during the first set of experiments and the lowest salinity value observed during 1979 experiments was 18.70‰ in June and the same showed an increase upto 39.18‰ in April. The extremely low and high saline conditions in which the prawns were grown in the two years become all the more significant when the results obtained in respect of growth rate in two seasons are considered. The results obtained during the present experiments indicate that in both the seasons, even under extreme salinity conditions steady growth rate was maintained as it would be seen from the Figs. 3 and 4. Same was the case with temperature also. It was found that temperature as high as 38°C recorded in April 1979 did not have any adverse effect on the growth of the prawns. Thus it becomes evident that a range in salinity between 4.45‰ and 39.16‰ and a temperature maximum upto 38°C would in no way affect the survival and growth of *P. indicus*.

The pattern of growth rate of the species in the initial 20 days after stocking and the subsequent 20 days was analysed and the results are presented in Table 3. In spite of the highly varying densities of stocking (50,000 to 70,000/ha in 1978 and 56,000 to 252,000/ha in 1979), the average growth rate during the first 20 days after stocking in both the years was regis-

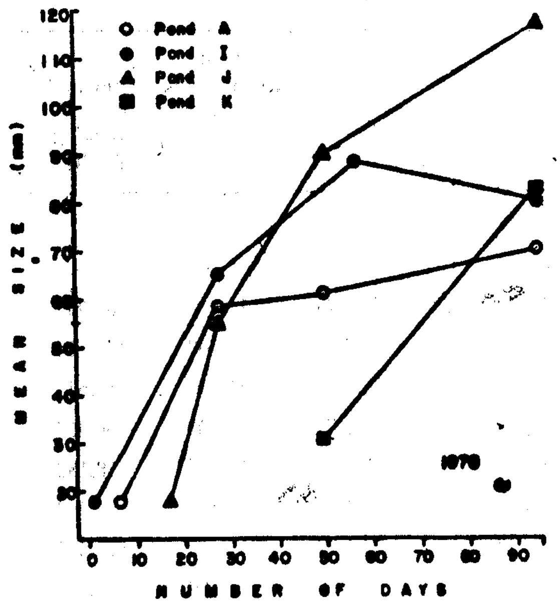

Fig. 3. Growth rate of *P. indicus* in different ponds in 1978.

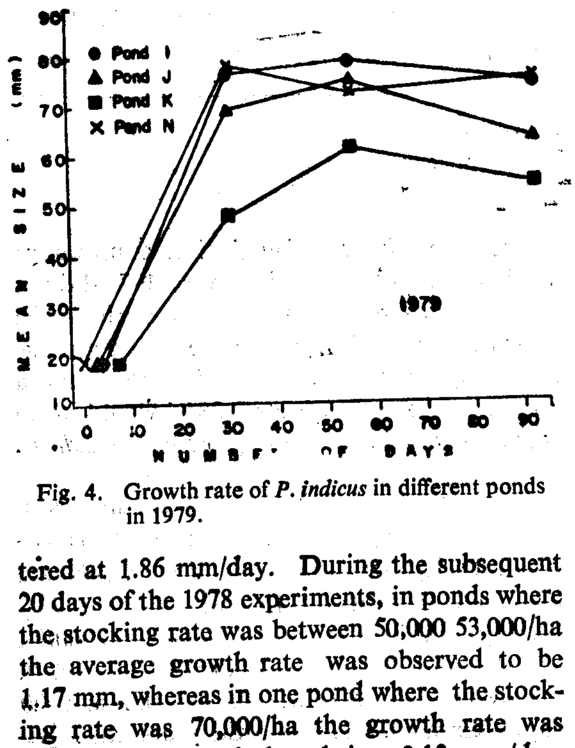

Fig. 4. Growth rate of *P. indicus* in different ponds in 1979.

tered at 1.86 mm/day. During the subsequent 20 days of the 1978 experiments, in ponds where the stocking rate was between 50,000 53,000/ha the average growth rate was observed to be 1.17 mm, whereas in one pond where the stocking rate was 70,000/ha the growth rate was found to be much less being 0.13 mm/day. In the experiments conducted during 1979, concomitant with the increased stocking rate, the growth per day was low, being 0.78 mm only.

Post-stocking Monitoring of the Environmental Parameters

During 1978 experiments, the water temperature in the ponds ranged between 30.18°C in June and 34.63°C in October. Similarly, salinity values showed a minimum of 5.34‰ in August to a maximum of 11.90‰ in June. The low salinity even in the month of September was due to the heavy rains and subsequent flooding that occurred on account of very active north-east monsoon. The oxygen values varied from 3.64 ml/l in July to 5.80 ml/l in September. The monthly average values of salinity, temperature and oxygen for ponds A, I, J and K are presented in Table 4.

The results of the post-stocking monitoring of the environmental parameters conducted in 1979 are presented in Fig. 5. The ambient water temperature recorded a minimum of 30°C in January and a maximum of 38°C in March. During the period January-February and May-June, the temperature was comparatively low, but during the summer months of March-April, the temperature values were quite high. There was a marked variation in the salinity which showed a minimum of 18.7‰ in June and a maximum of 39.18‰ in April, thus recording more than 100% increase during the course of the experiment. Though the ponds were connected by canals, it was obvious that the salt content in the mud also influenced the salinity of the water. However, the sudden lowering of the salinity due to the monsoon rains had greatly influenced the environmental conditions. It was observed that the prawns could withstand such extreme variations in salinity probably due to the interstitial chlorides available in the area (Fig. 5).

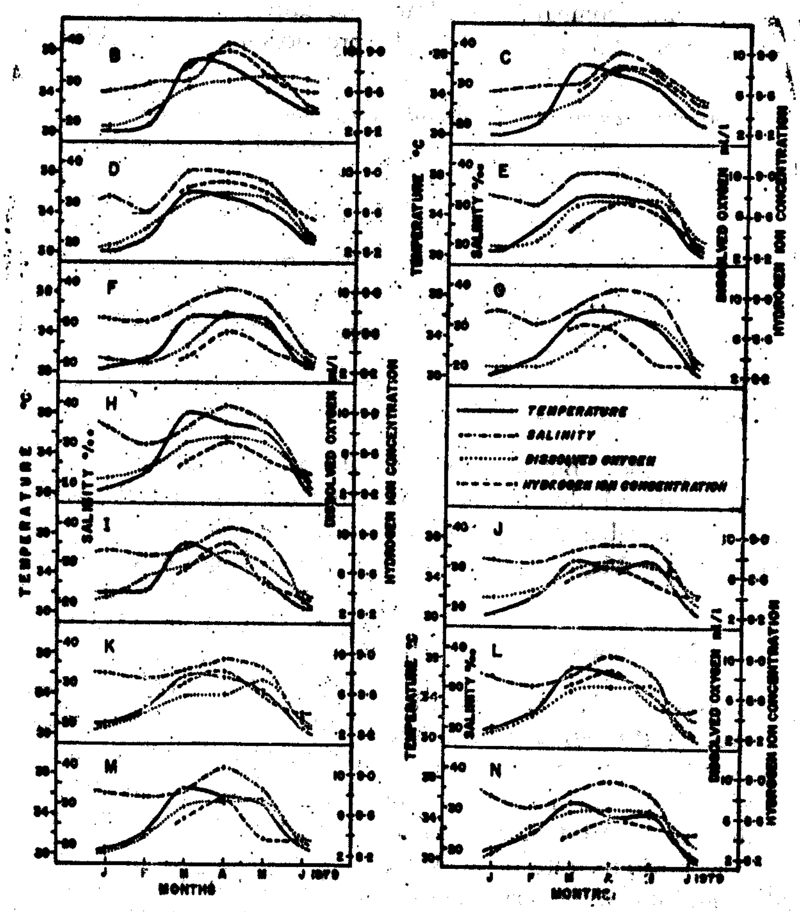

Fig. 5. Post-stocking environmental features in different ponds in 1979.

TABLE 3. *Average growth rate per day (mm) of* P. indicus *during the first 40 days in 1978 and 1979*

Ponds	1978 Duration		1979 Duration	
	1st 20 days	21-40 days	1st 20 days	21-40 days
A	2.00	0.13	—	—
I	1.72	1.15	2.23	0.75
J	2.62	1.20	1.90	0.83
K	1.14	1.15	1.30	0.65
N	—	—	2.00	0.88

The dissolved oxygen content showed substantial variations, with comparatively low values ranging between 2.3 and 8.58 ml/l

TABLE 4. *Average monthly values of hydrological parameters during the culture period in 1978 (for ponds A, I, J and K)*

Parameters	June	July	August	September	October
Temperature (°C) ..	30.18	31.3	31.0	30.87	34.63
Salinity (‰) ..	11.90	6.41	5.34	6.14	—
Dissolved oxygen (ml/l) ..	5.59	3.64	5.28	5.80	—

during the first half period. But no apparent adverse effect was noticed due to the low oxygen content. The pH values ranged between 8.3 in July and 8.75 in May.

DISCUSSION

In recent years several workers have recorded the rate of growth of *Penaeus indicus* in the culture systems as well as in the natural environment. The rates of growth recorded were found to vary due to several factors such as size of the seed at stocking, rate of stocking, environmental conditions of the fields and the method of culture operations followed. George (1975) made some observations on the growth rate of *P. indicus* in a paddy field in Cochin area where non-selective stocking was done and recorded a growth rate of 0.498 mm per day for a period of 89 days. Growth rate was studied by Suseelan (1975) on prawns in the natural ecosystem and he reported that *P. indicus* grew at the rate of 1.00 mm per day for a period of 89 days. The present observation of 1.5 mm per day during the first 40 days of culture is found to be comparable with those recorded by Sultan *et al.* (1973), Mammen *et al.* (1980) and Muthu *et al.* (MS).

Muthu *et al.* (MS) conducted studies on the growth rate of prawns in the experimental ponds at Narakkal, Cochin and showed that the growth rate of *P. indicus* was inversely proportional to stocking density. However the present studies revealed that even in higher stocking densities *P. indicus* grew at a faster rate to attain an average size of 55 mm (growth per day being 1.86 mm) during the first 20 days of stocking. Thus the present experience suggests that about 123,000 seeds of *P. indicus* could be stocked in a reasonably productive field of 1 ha and reared upto a size of 55 mm without any supplementary feeding; further retention of the stock necessitates either thinning of the stock or intensive feeding to obtain sustained growth rate.

In view of the lack of information on the behaviour of prawns in culture ponds under extreme environmental conditions such as low salinity and high temperature, the present culture experiments were also aimed at understanding the impact of the above conditions on the growth and survival of prawns in confinement. Therefore the two sets of farming were carried out in two different seasons, one during the south west monsoon period which was characterised by extremely low salinity and the other during the pre-monsoon summer months when the temperature of the water rose to higher levels.

It has been observed that in the initial 20 days after stocking the prawns grow at a faster rate and this would encourage adoption of the practice of nursery farming. The seeds can be densely stocked in one or two ponds and after 20 days they can be transferred to various grow out ponds. This would minimise the mortality rates and difficulties connected with the handling of the seeds.

The causative factors for the low growth rate during the second twenty days other than the stocking density have also been investigated. It was observed that extreme fluctuations in the environmental parameters like water temperature and salinity have influenced the growth to a great extent. Inadequate water circulation due to weak flow into the feeder canals and resultant stagnation of water in some of the ponds might have added to this problem. Further, it was observed that in certain shallow ponds there was accumulation of dead bivalve shells in the substratum. It is possible that in the shallow ponds the increase in water temperature might have affected the dissolution of calcium carbonate and resulted in an increase in the pH of the water. However, further investigations are required to corroborate this view.

As far as mariculture practice is concerned, the Quilon-Neendakara area is a virgin ground. The main prospects are the availability of plenty of unused water area. The problem of water contamination in this area is the result of widespread practice of coconut husk retting which produces lot of hydrogen-sulphide and high rate of oxygen demand. These areas have to be avoided when the question of site selection is considered. Although, other species are available, considering the demand and monetory returns, *P. indicus* can be given priority in prawn farming. Availability of plenty of seeds in the area makes the task easy for the farmers in collecting adequate number of seeds. Neendakara is one of the main marketing centres for seafood in the State. This added facility for preservation and marketing the harvest is of great advantage to the farmers in this area.

Quilon is one among the very few districts in the State bestowed with the benefit of having financing agencies like Small Farmers Development Agency (SFDA) and Integrated Rural Development Programme (IRDP) which give subsidised loans to agricultural farmers on easy repayment instalments. Considering the awareness among the people of the potentialities of aquaculture, of late, these agencies have come forward to help the fish farmers with financial assistance. The SFDA has already drawn up a scheme (involving Rs. two lakhs at the first stage) to take up prawn culture in the low lying coastal saline tract of Quilon District by the small and marginal farmers.

The encouraging results obtained on the growth rate of prawns during the present experiments proved beyond doubt that Ashtamudi Lake area is one where faster growth rate for prawns could be expected. Subsequent to the present study, several farmers have taken up prawn culture in this area and promising results are being reported. Besides, under the Lab-to-Land programme, the Central Marine Fisheries Research Institute has successfully carried out intensive prawn culture operations in the farms of 14 adopted farmers. Hence, the present attempt was successful in two spheres ; in identifying new areas for prawn culture as well as in popularising and transferring scientific know-how in mariculture.

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UTILISATION OF SALINE GROUNDWATER FOR PRAWN AND FISH FARMING

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ABSTRACT

In the Gurajanapalli-Penuguduru belt, located at about 8 to 10 km from Kakinada in Andhra Pradesh, a large number of salt pans depend on saline ground water for the manufacture of solar salt. Such ground water at the point of its emergence, was found to have a pH of 6.8, PO_4-P of 0.12 ppm, NO_3-N in traces, dissolved oxygen nil, free carbon dioxide 60 ppm, and total alkalinity 884 ppm with salinity varying between 28.54 and 30.00 ppt. Such water, after flowing through very shallow evaporation channels, when fed into two ponds located at a distance of 200 m from the point of its origin, was found to show improvement in all the above parameters and become suitable for aquaculture.

The pre-impoundment characteristics of the pond soil were studied. After application of a bi-monthly dose of inorganic fertilizers namely, urea and single superphosphate at a rate of 100 kg each/ha a rapid improvement in the nutrient status was observed both in the soil and water phases. Thick mats of blue green algae developed within a month. The ponds were then stocked with juveniles of tiger prawn *Penaeus monodon* (Fabricius), 25 to 55 mm in total length, at a rate of 20,000 fry/ha and of milkfish *Chanos chanos* (Forsskal), 65 to 69 mm in total length at a rate of 50,000 nos/ha. In the case of *Penaeus monodon* a gain of 89.6 mm in average length and 15.8 g in average body weight was recorded in 75 days, whereas milkfish showed a gain of 227 mm in length and 180 g in weight in 63 days. Changes in the abiotic characters and management measures resulting in maintaining them at levels conducive for fast growth of the cultured species are described.

INTRODUCTION

THOUGH considerable information is available on the fish and prawn culture practices in conventional brackishwater impoundments and ponds, that receive water from estuaries and the connected canal systems, there is dearth of information on the possibility of utilising saline ground water facilities for brackishwater aquaculture.

During a bench mark survey of fish farmers carried out in connection with the I.C.A.R. Lab-to-Land Programme, the authors came across the Penuguduru-Gurajanapalli belt situated at about 8 to 10 km from Kakinada in Andhra Pradesh where there is an active salt manufacturing industry spread over an area of 1,200 ha exclusively depending on the underground saline water resources for making salt. Realising the potentiality of the area for brackishwater farming, one farmer was encouraged to construct two ponds with a total water spread of 0.47 ha and fish and prawn farming technologies were demonstrated. The results obtained in the above endeavour are presented in this communication, thereby throwing open a new and potential ecosystem for brackishwater aquaculture.

The authors are indebted to the Project Coordinator, A.I.C.R.P. on Brackishwater Farming for the guidance. They are very grateful to the authorities of Andhra Pradesh Agricultural University for providing the necessary,

facilities for this work. They also convey their thanks to Sri G. B. V. Krishna Rao, the Golden Jubilee Farmer of the I.C.A.R. for his co-operation throughout the period of this work.

The Farm

The farmer leased out 8 ha of land from the Salt Department for 20 years, out of which only 1.4 ha was used for construction of condenser and crystallization beds and the remaining area was lying fallow except for digging a system of shallow canals for circulation of the ground water after pumping out from two filter points at a depth of 11.4 m.

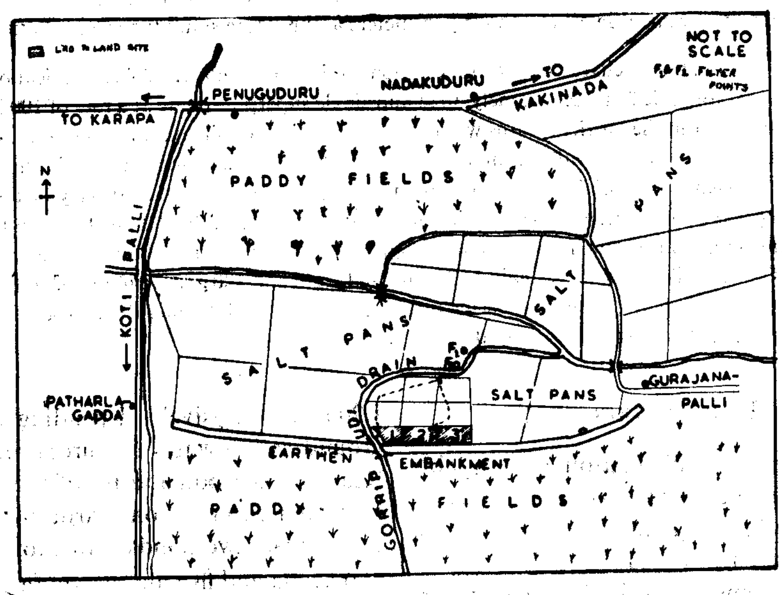

Fig. 1. Map of Lab-to-Land site at Patharlagadda.

In Fig. 1 is given a sketch of the area of investigation. It can be seen that the Paddy fields and Salt pans exist side by side with an earthen embankment separating them. The salt pans are traversed by two freshwater discharge canals which join and flow parallel to the Gurajanapalli road to ultimately join the sea near Chollangi. The ponds are constructed in one corner of the area proximal to freshwater source. Between the filter points and the ponds there is a distance of about 200 m but there is a 500 m long canal system serving as evaporation channel and for the circulation of water.

Ecology

Characteristics of groundwater

The temperature of the ground water varied between 29.2°C in September and 33°C in April. The pH fluctuated between 6.8 and 7.1. While the dissolved oxygen was nil, the free carbon dioxide showed high values of 60 to 140 ppm. The total alkalinity values too exhibited a very high range of 884 to 1,086 ppm. The ranges for the salinity and the phosphates were 28.54 to 32.52 ppt and 0.03 to 0.12 ppm respectively with the nitrates only in traces.

Canal system

The ground water with the above characteristics which are detrimental to animal life, when flowing through the meandering canal system was observed to lose the free carbon dioxide and consequently reducing the total alkalinity, but improve the dissolved oxygen content through diffusion of gases from and into the atmosphere. By the time the ground water reached the pond, the salinity was observed to be as high as 43.7 ppt in March, thereby requiring a freshwater source for dilution of the water in the pond. The dissolved oxygen improved to 7.6 ppm and free carbon dioxide reduced to only 10 ppm. The concentration of phosphates was 0.08 ppm but that of the nitrates only in traces.

Pre-fertilization characteristics of the soil

The soil is of clayey-loam type and impervious to water. The values of organic carbon and available phosphorus were 0.36% and 1.6 mg/100 g soil respectively. The available nitrogen could not be analysed for want of facilities.

DESCRIPTION OF PONDS

Two ponds measuring 115 m × 22 m and 89 m × 25 m were constructed with an average depth of 30 cm leaving a few deeper pits which offered protection against the heat of the day. Along the margin of the ponds there was exuberant growth of grasses with excellent periphyton offering shelter as well as additional grazing areas for the prawns and the fishes. Branches of thorny trees such as *Prosopis* sp. put in the ponds served not only against the poachers but served as additional grazing areas with a lot of periphyton developed over them within a week of keeping them in the ponds.

Pond preparation

The pond bed was exposed to the sun and allowed to crack. After inundating the pond to a depth of 15 cm, a bimonthly dose of urea and superphosphate was added @ 100 kg each per ha per annum. Half of the above quantity was dispersed on the pond bed after mixing with the pond soil and the other half broadcast as solution. The first signs of algal development were seen on the 4th day of fertilization. By the 8th day their development was considerable and within a fortnight dense mats of bluegreen algae comprising of *Anabaena* sp., *Oscillatoria* sp., *Lyngbya* sp. and *Spirulina* sp. and the green alga *Chlorella* sp. developed on the pond bed. The fauna associated with algal bed were ciliates, *Brachionus* sp., copepods and very few nematodes.

Post-fertilization characters of ponds

In Fig. 2 are given the fluctuations of salinity, dissolved oxygen, free carbondioxide, nitrates and phosphates of the pond water and groundwater to bring out the contrast between them. It can be seen that the balance of dissolved gases became conducive for aquaculture. The concentration of nitrates which were only in traces in groundwater, maintained a range of 0.15 to 0.26 ppm in the ponds. Phosphates also registered a rise in values with a range of 0.08 to 0.20 ppm in the pond as against 0.03 to 0.12 ppm in groundwater.

The pH of the pond water became slightly alkaline (7.1 to 8.2) and the total alkalinity reduced to a range of 86 to 189 ppm.

In the soil phase the available phosphorus increased from the prefertilization value of 1.6 mg/100 g soil to 3.2 to 4.0 mg/100 g soil. The organic carbon values also rose from 0.36% to 0.69%.

During the culture period the ponds were fertilized on two more occasions with the same chemical fertilizers *viz.*, urea and superphosphate at the same dose.

Stocking

One pond 0.22 ha area was stocked only with fry of *Chanos chanos* (Forsskal) on 14th and 19th May, 1979 @ 5,000/numbers per ha

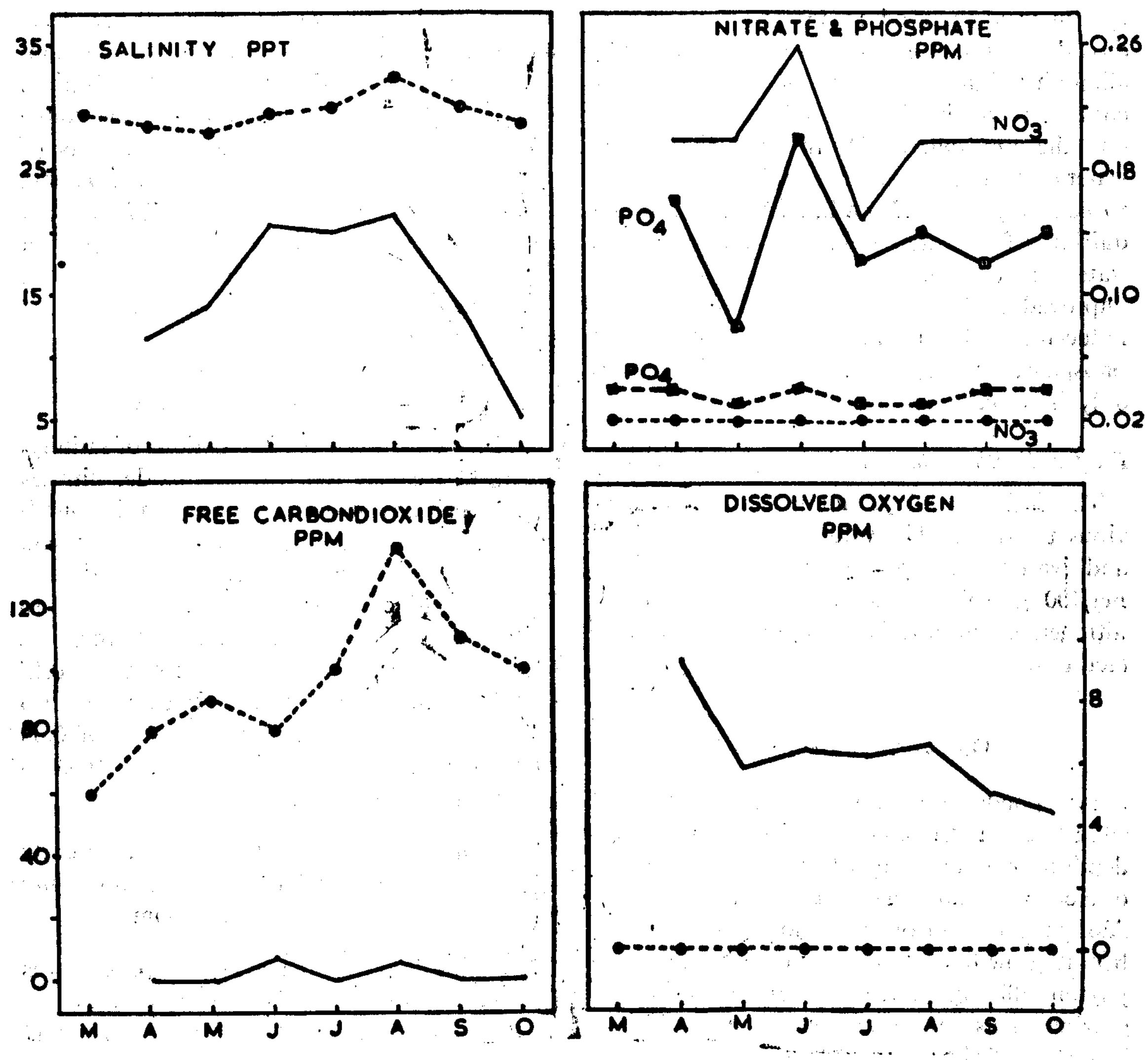

Fig. 2. Some chemical parameters of ground (- - - - - - - -) and pond waters (————).

in the length range of 35 to 92 mm and an average size of 63.4 mm/1.2 g and 69.0 mm/1.5 g.

Another pond of 0.25 ha was stocked on 13th June, 1979 only with fry of *Penaeus monodon* Fabricius in the length range of 16 to 58 mm with an average length of 36.9 mm @ 20,000 fry/ha.

Results

From Table 1 it can be seen that the two groups of *chanos* stocked with a difference of only five days and a difference of only 5.6 mm in their average lengths got widely separated with progression of growth. Thus after about 4½ months of stocking the two groups had average sizes of 334.4 mm / 237.5 g and 374.2 mm / 345.2 g.

During the above culture period, supplementary feed in the form of powdered mixture of rice bran, ground nut oil cake and fish meal in equal proportions was given @ 3% of the body weight of *chanos* only for 50 days from 18th August. The growth was very much accelerated during the period when supplmentary feed was given. At the time of final harvesting on 17th and 18th of October, 1979 908 *chanos* weighing 295 kg were recovered. The length range was 315-465 mm with an overall average size of *chanos* and 360.8 mm/ 324.9 g with percentage survival of 82.5 A yield of 1,340 kg/ha was obtained in 5 months of rearing.

In Table 2 the percentage of frequency of the different size groups of *Penaeus monodon* on the stocking date as well as on sampling dates was given. It can be seen that there is a progression of the modal length groups marked with an asterisk in different months. Thus specimens of the modal size group 31-40 mm in June grew to 121-130 mm in October. The average size at harvesting was 123 mm/16.17 g with a survival of 66.8%. A production of 216 Kg/ha was obtained in 135 days.

TABLE 1. *Growth and production of* Chanos chanos *in a 0.22 ha pond at Patharlagadda receiving saline groundwater*

	Group I			Group II		
	N	Length range	Av. size (mm/g)	N	Length range	Av. size (mm/g)
Stocking						
14th & 19th May 1979	400	52-90	63.4 (1.2)	700	35-92	69.0 (1.5)
Sampling						
June 4, 1979	19	143-172	157.3 (32.9)	60	202-226	212.2 (73.8)
July 4, 1979	35	190-238	215.0 (78.4)	54	245-320	281.7 (169.5)
Aug. 4, 1979	19	250-280	260.1 (150.0)	67	275-365	307.2 (200.0)
Sept. 4, 1979	43	245-320	291.9 (176.7)	52	325-390	346.7 (281.3)
Oct. 6, 1979	8	300-335	334.4 (237.5)	45	330-410	374.2 (345.2)

DISCUSSION

An average weight of 324.9 g in 5 months time for *Chanos chanos* at a stocking density of 5,000 numbers per ha in the present demonstration seems to be a record for Indian conditions. This is higher than the average weight of 314.6 g and 226.5 g in 6 months, recorded in Santhome Fish Farm at a lower stocking density of 3,500 nos/ha and 166.3 g to 189 g at stocking densities of 4,000 and 6,000 in combination with prawns (Sundararajan, 1977; Sundararajan *et al.*, 1978). Dwivedi and Reddi (1976) reported from Kakinada an average growth of 380 g in one year for *chanos* without supplementary feed.

Similarly from Indonesian ponds also lower average weights of only 128 to 276g were obtained in 3 monhts, by stocking comparatively larger stocking material of 29.2 to 36.4g of average weight were reported (Ranoemihardjo *et al.*, 1975). Schuster (1958) gives the average weight of pond reared *chanos* in 6 months as 250 g for Indonesia, 300 g in Philippines and 150 g in Taiwan indicating that in tropical countries the growth is faster. The present production of 1,340 kg/ha in 5 months also is higher than the yield reported by the above authors. Under intensive culture of milk-fish with emphasis on supplementary feeding, productions of 1,000-2,000 Kg/ha/annum are obtained in Taiwan and 350 to 750 kg from Philippines (Hora and Pillay, 1962).

The average size of 123.4 mm/16.17 g in 4½ months for *Penaeus monodon* in the present case is more or less same as that reported by Delmendo and Rabanal (1956) from the Philippines. The average monthly increment of 19.3 mm recorded by the present authors is higher than what was reported by Subrahmanyam (1973). However, the rates of growth and production under monoculture reported from Santhome (Sundararajan, 1978) and Kakdwip (Verghese *et al.*, 1975; Jhingran, 1977; Verghese, 1978) are higher than those obtained in the present study. The reason seems to be the abundance of bottom macrofauna in those ponds and their absence in the Patharlagadda

TABLE 2. *Growth and production of* Penaeus monodon *under monoculture in a* 0.25 *ha pond at Patharlagadda receiving saline groundwater* (*Modal length groups indicated with asterisk*)

Size group (mm)	Stocking	Sampling Dates			
	Frequency (%)	4.7.'79 Freq. (%)	4.8.'79 Freq. (%)	4.9.'79 Freq. (%)	6.10'79 Freq. (%)
Total No. stocked 5,000					
11-20	20.0	..	..	..	..
21-30	20.0	..	..	..	..
31-40	*58.5	3.0	..	..	..
41.50	..	9.1	..	..	..
51-60	1.5	12.1	1.5	..	..
61-70	..	*45.5	14.5	..	..
71-80	..	6.1	*24.6	..	..
81-90	..	12.1	14.5	20.3	..
91-100	..	12.1	10.1	*26.8	..
101-110	..	..	20.3	26.1	25.0
111-120	..	..	14.5	13.8	23.8
121-130	..	..	..	10.1	*35.7
131-140	..	..	..	2.9	7.1
141-150	..	..	..	..	4.8
151-160	..	..	..	..	3.6

Stocking data

Date: 13-6-1979
No. stocked: 5,000
Density: 20,000/ha
Size at stocking: 36.9 mm/0.9 g
Total weight of stock: 4.5 kg.

Harvesting data

Dates: 17th & 18th Oct., 1979
No. recovered: 3,340
Qty. harvested: 54 kg
Net production: 198 kg/ha/135 days

ponds which receive only pond water. The annual production of 1,956 kg of fish and 264 kg of prawns per ha reported from Kakinada (Dwivedi and Reddi, 1976) are again comparatively lower than the yields obtained in the present endeavour.

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A SAMPLING DEVICE FOR THE QUANTITATIVE ASSESSMENT OF PRAWN AND FISH SEED RESOURCES IN THE ESTUARINE AREAS

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ABSTRACT

The need for a suitable and efficient sampler for the quantitative assessment of prawn and fish seed resources of the estuarine areas was very much felt during the field surveys. Dragging or pushing a net was beset with several difficulties in the estuaries and backwaters. To overcome these, several devices such as drag nets, trolley type pushing nets, scoops, traps, etc. were tried and finally a simple and at the same time efficient sampler was adopted.

The Quantitative Seed Sampler (QSS) deviced for sampling in the estuaries and backwaters is an aluminium foldable cage of the size of 100 × 100 × 75 cm, open at top and bottom. All the four sides of the cage are covered with nylon netting. Besides this, a square scoop net of 95 × 95 cm which would almost fit into the cage, is used to scoop out the seeds trapped inside the cage. The method of operation is to suddenly place the cage in a water area so as to firmly settle at the bottom ensuring complete prevention of even the fast swimming organisms from the cage. All the prawn and fish seeds once trapped in the cage could conveniently be collected using the scoop net. Fabrication of the sampler, materials required, dimensions, its operation, efficiency studies made, advantages and disadvantages, etc. are discussed in detail in this paper.

INTRODUCTION

FOR SUCCESSFUL Aquaculture practices, one of the factors needed is the knowledge about the availability of natural seed resources of the desired fishes or prawns. Aquaculturists need not always depend upon the laboratory reared seeds and this is not necessary also when the seeds are available in the wild in required quantities. The shallow areas of estuaries and backwaters (right from the water edge) have been found to be an excellent habitat for fish and prawn larvae of cultivable species. Their abundance has been found to vary with areas and seasons. Hence, a quantitative assessment of the natural seed resources in space and time becomes a prerequisite for the successful farming of brackishwater prawn and fishes.

While conducting surveys for the assessment of prawn and fish seed resources of cultivable species in estuaries and backwaters of Kerala, the need for a suitable sampler for the quantitative estimation of the seed resources was felt very much. Several gears such as drag nets, trolley type push nets, scoops, traps, cages, etc. have been experimented. Finally, an entirely new one was selected being the most efficient. The present paper gives the details of the fabrication and operation of this sampler including the materials required, dimensions and its efficiency (Table 1 and 2). A comparative study of the catch efficiency of the present sampler with another type of quantitative sampler was also made (Table 2).

The authors express their sincere thanks to

Dr. E. G. Silas, Director, Central Marine Fisheries Research Institute, Cochin for his suggestions, constant advices and encouragements during the course of these experiments. They are also indebted to him for critically going through the manuscript and offering many valuable suggestions. They wish to record their thanks to Shri S. Thiagarajan at the Regional Centre of the Central Marine Fisheries Research Institute, Mandapam Camp for placing the drag net designed by him at their disposal for comparative studies.

Methods employed in quantitative seed sampling

Strawn (1954) described a 'one-man push net' used in shallow water flats by Florida bait shrimp fishermen and reported its superiority over a seine for collecting seeds in rooted vegetation. Donald and Anthony (1958) fabricated another kind of one man operated push net, and used it for the quantitative sampling of shrimp in shallow estuaries among vegetations. The net is pushed at a standard pace for a prescribed measured distance. Velon screen (a nylon seine) is employed to estimate the quantitative assessment of prawn seeds present in an area. Two men have to drag the screen for a fixed distance and estimate the number of seeds in terms of No./square area. The same velon screen method is also used to calculate the number of seeds collected per man hour. But this method will not give an insight into the actual quantity of the seed resources present and has only commercial application. One kind of drag net was used by Thiagarajan (Per. comm.) for the quantitative estimation of prawn and fish seeds in shallow sandy areas.

Structure and fabrication of the present sampler

The sampler consists of two parts, a cage and a scoop. The frame of the sampler is made of anodised aluminium angles and frames of 3 mm thick and 25 mm width. The materials required for making the sampler are given in Table 1. The size of the cage is 100 × 100 × 75 cm. The cage is made into two foldable pieces. Each piece consists of two sides of the cage, each side being attached by a pair of aluminium hinges. When each piece is folded it will be in the form of a rectangle and this shape facilitates easy carrying of the sampler from place to place in the field. The two pieces of the cage, can easily be assembled together, by means of latches provided at the appropriate places to form a cage. Once the latches are screwed tight there should not be any gap on any side of the sampler. Equidistant holes at 10 cm interval are made on the frames including the corners for passing a 4 mm diameter nylon rope to fastening the velon screen. To prevent undue bulging of the netting while sampling with the scoop, plain aluminium flats are to be fixed horizontally and vertically to each side of the cage. If the net is bulged out it will leave space on sides which may allow the larvae to evade the scoop. The nylon netting for the cage is to be cut into four pieces of 1 × 0.75 m size and to the four edges of each piece the canvas cloth of 10 cm width is to be stitched to strengthen the edges. Each piece of the nylon netting is tied to each side of the frame.

The frame of the scoop is also made in four pieces of aluminium angles each one of 95 cm in length. Equidistant holes are to be made on the frame as in the case of the cages. The net for the scoop frame is made in the form of a shallowscoop by stitching together four triangular pieces of nylon netting. This netting is attached to the frame by means of the nylon rope.

The cage when completed and assembled can cover an area of 1 m^2 or can contain 0.75 m^3 of water. The cage and the scoop will have a total weight of 7.5 kg.

Operation of the Quantitative Seed Sampler

The sampler is assembled into a cage on land and carried by a single man to the sampling area without making much disturbance. It is suddenly placed in water ensuring that the sampler has settled properly at the bottom without gaps between the bottom frame and the substratum. Now the movement of organisms is restricted within the cage and escape from the cage is prevented. The depth at the sampling area is measured inside the cage at the centre. The scoop is used by two persons to collect the organisms from the sampler. The scooping is repeated until all the organisms trapped in the sampler are removed. Similar sampling is to be repeated at three or four places in a centre to get the correct data on the occurrence of the seeds in that area.

The values obtained from the analysis can be expressed either volumetrically (No. per m^3) or area wise (No. per m^2) and finally this can be used for the estimation of the seed resources of a particular region.

Comparative study of seed sampling efficiency

The Quantitative Seed Sampler described here and another type of drag net fabricated by Thiagarajan (Per. comm.) were tried at Paruthithodu in the Cochin Backwaters to test the efficiency of one over the other. Each net was operated at four separate but adjacent places. The former sampler filtered a total of 1.9 m^3 of water and the latter filtered a total of 19.45 m^3 of water. The results thus obtained are given in Table 2.

Discussion

For an area-wise estimation of the seed resources, the most important factor is to collect all the seeds present in the sampling area. The Florida type push net described by Strawn (1954) operates efficiently in submerged vegetation such as turtle grass. However, a satisfactory index of abundance based on a standardised unit of effort could not be obtained using this type of net. De Silva (1954) used the Florida type push net. But avoidance of the sampler by some species of prawns was noticed by him. A commercial prawn seed collection device for operating from motor boats, piers or platforms has been fabricated by Fontain *et al.* (1972) and found very effective. A system of quantitative estimation of the seed obtained has also been given. But the massiveness and complexity of the equipment minimise the operational ease to a great extent. Donald and Anthony (1958) who designed another type of push net admit that the organisms caught in their net may not be in proportion to their abundance. They have noticed avoidance of the sampler by some species of prawns. Use of a velon screen for the quantitative estimation of seed resources is not a correct method. Tests have proved that use of cast net was inefficient in giving a correct estimate of the seed resources.

Dragging or pushing a net or using a cast net, velon screen, etc. in muddy estuarine areas is extremely difficult and estimation of the seeds based on such collections may be biased because of the following reasons. (1) Speed at which the sampler is dragged cannot be maintained, (2) complete removal of seeds present in the sampling area is not possible, (3) there will be more tendency for the larvae and juveniles to avoid the samplers and (4) in the case of drag net, since two persons have to walk in front of the net the disturbances caused due to this may result in the escape of larvae from the sampling area.

The Quantitative Seed Sampler described in this paper overcomes almost all the drawbacks mentioned above. Since the sampler is used at a fixed place, the problems connected with speed maintenance do not come into the picture. Secondly, the sampler is placed suddenly at an undisturbed area so that the entire seeds are trapped. Once the sampler is placed,

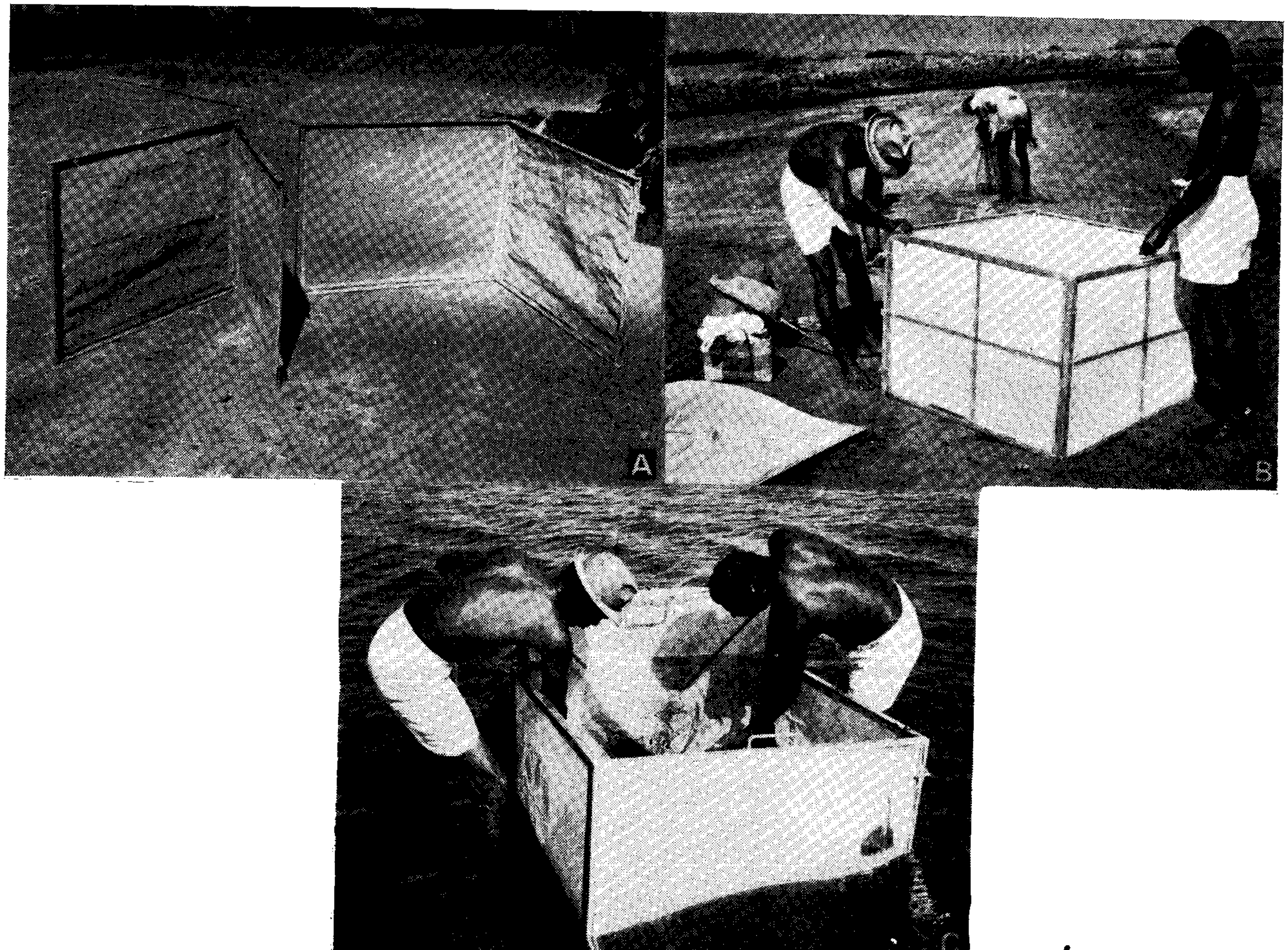

PLATE I A - C. The Quantitative Seed Sampler (QSS), its assembly and operation. A. the cage in pre-assembling condition, B. the cage in assembled condition and C. the sampler is in use and the seeds are being scooped out.

TABLE 1. *Requirements of different materials for the fabrication of Quantitative Seed Sampler*

Part of the sampler	Aluminium angles		Aluminium flats		Nylon netting		Canvass 10 cm width (m)	4 mm thick Nylon rope (m)	Hinges (No.)	Latches (No.)	Handles (No.)
	Length of each piece (m)	No. of each piece	Length of each piece (m)	No. of each piece (m)	Size & shape	No. of pieces					
	1.00	8	1.00	4	1× 0.75						
Cage	0.75	8	0.75	4	rectangular	4	14	15	8	4	2
Scoop	0.95	4	—	—	triangular piece each side having 95 cm length	4	8	5	—	—	2
	Total	20		8	8	8	22	20	8	4	4

TABLE 2. *Results of comparative study of efficiency of two Quantitative Seed Samplers*

Name of the Seed Sampler	Sampling Number	Time (hrs.)	Depth of water at the collection site (cm)	Nature of the bottom	Quantity of water filtered (m³)	Organisms found in the sample: *Penaeus indicus*	*Metapenaeus dobsoni*	*Macrobrachium idella*	Caridian prawns	*Scylla serrata*	*Etroplus maculatus*	*Glassogobius* spp.	*Syngnathus* sp.	*Aplocheilus* sp.	*Tetrodon* sp.	*Solea* sp.	Estimated number * of organisms per m³
Quantitative Seed Sampler	1	1030	15	Sandy & muddy	0.15	8	145	—	—	2	—	—	1	—	—	—	1040
	2	1100	60	Sandy & muddy	0.60	—	14	—	—	—	2	2	—	3	—	—	35
	3	1215	55	Sandy	0.55	1	24	—	—	—	—	3	—	2	—	—	55
	4	1230	60	Sandy	0.60	2	3	—	—	—	—	1	—	3	—	—	15
					1.90	11	186	—	—	2	2	6	1	8	—	—	114
Drag Net	1	1130	60	Sandy & muddy	7.80	1	44	—	1	—	1	3	—	—	2	1	7
	2	1145	25	Sandy & muddy	3.25	32	41	—	—	—	—	—	—	10	—	1	26
	3	1300	30	Muddy	4.20	14	—	3	22	—	—	—	—	—	—	—	9
	4	1330	30	Muddy	4.20	5	21	1	16	2	1	—	—	—	—	—	11
					19.45	52	106	4	39	2	2	3	—	10	2	2	11

* Estimated number of organisms per m³ has been rounded of to the nearest full number.

the seeds trapped in can be conveniently taken out with the aid of the scoop net.

As far as the trapping efficiency of the present equipment is concerned the comparative results obtained from the two types of samplers tested in the field weigh in its favour. From Table 2 it is clear that the Quantitative Seed Sampler described here is more efficient over the drag net. It is true that three additional species were collected in the drag net, but this could be attributed to the extra coverage of area by the drag net.

The only drawback of the present sampler is that it can be used only in shallow areas where water depth is less than 75 cm, but again this is not a major problem because the seeds especially of prawns are mainly confined to the shallower areas of the estuaries and back-waters. Moreover, for culture purposes seed collection is done at very shallow waters having less than one metre depth.

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SOME OBSERVATIONS ON PENAEID PRAWN SEED RESOURCES IN THE VELLAR ESTUARINE SYSTEM (PORTO NOVO)

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ABSTRACT

Seeds of three species of Penaeid prawns *Penaeus indicus*, *P. monodon* and *P. semisulcatus* were collected from three regions of the Vellar estuarine system on year round basis. In the overall abundance, *P. indicus* was dominant in the estuarine system followed by *P. monodon* and *P. semisulcatus*.

Two peaks were observed in the penaeid prawn seeds population, the primary peak being during September-October and the secondary peak in January-February. *P. indicus* and *P. semisulcatus* were more towards the lower reaches of the estuary, their abundance gradually decreasing in the upper and middle reaches. *P. monodon* was abundant in the middle reaches which possess many creeks with luxuriant algal vegetation. The hydrographical feature influencing the penaeid prawn seed population were discussed. Relatively less prawn seeds were encountered during late monsoon (November-December) and early summer (April-May). Mortality rate of the postlarvae of these penaeid prawns during transportation was also studied.

INTRODUCTION

TAMIL NADU has an extensive coastal belt of 1,000 km with 44 estuaries, 3 backwater marshes, one salt water lake and one mangrove swamp. These are very rich potential nursery grounds for almost all commercially important crustaceans.

In Tamil Nadu, number of small farmers are involved in prawn culture utilising backwater marshes and other low lying areas. Considerable quantity of prawn seed is available in estuarine and other lower saline biotopes. Data collected from the Vellar Estuary indicate that prawn seeds are available here in vast quantities for stocking.

Throughout the period of observation, the Vellar Estuary at Porto Novo is connected with the sea having a permanent connection with Killai Backwater (Fig. 1). The tidal influence is felt upto a distance of about 12 km from the river mouth. During northeast monsoon (October to December), there is influx of flood water from the upper reaches of the river and from Veeranam Tank draining into it.

Informations on the recruitment of prawn larvae on the east coast and southwest coast of India are available from the publications of George (1962), Subramaniyam and Janarthana Rao (1968), Subramaniayam *et al.*, (1971), Rajyalakshmi (1972), Gemma Evangeline and Sudhakar (1972), Gopalakrishnayya and Janarthana Rao (1975), Subramaniyam *et al.*, (1978), Victor Chandrabose *et al.*, (1978) and Gopinathan (1978). However, information is wanting on prawn seeds from backwaters. The present investigation is on the seeds of fast growing and commercially valuable prawns amenable for developing aquaculture in the Vellar-Coleroon estuarine complex.

The authors are thankful to Shri C. Chellappan, I.A.S., Director of Fisheries for kind permission to present this paper and to Prof. R. Natarajan, Director, Centre of Advanced Study in Marine Biology, Annamalai University for valuable suggestions and criticisms.

MATERIALS AND METHODS

Regular weekly collections were made in the Vellar Estuary from April 1978 to March 1979. For this purpose three stations, *viz.*, the Marine Biological Station (Gradient zone), the Buckingham Canal (Tidal zone) and Mutlur (Fresh water zone) were selected (Ramamurthi, 1954) on the basis of availability of aquatic vegetation. These stations are located 1 Km, 3 Km and 10 Km respectively from the river mouth. Marine grass *Cymadocea isoctifolia* is available in station I, *Pandanus tectorius* is permanently located in the shallow margin of station II. *Cymadocea isoctifolia* and grass (Family *Cyperacea* and *Graminea*) are placed fairly on the shallow margins of the water in station III. A Velon screen dragnet (mesh 1/16) of 3 meters length and one meter width was used for seed collection. The net was operated near the algal flora, submerged plants near shallow margin and in pools. When dragging the net, the algal flora and submerged plants were strongly agitated by hand and by a small stick. Collections were made during low tide only. Since the aquatic vegetation provides adequate food, protection, and shelter, prawn seeds congregate more in such biota compared to other areas. Seeds were collected for one hour duration and were kept in plastic containers. Species were segregated in the field based on the colour pattern and then temporarily stored in Velon screen hapa at the State Government Estuarine Fish Farm of Porto Novo for supply of seeds to department or private fish farmers.

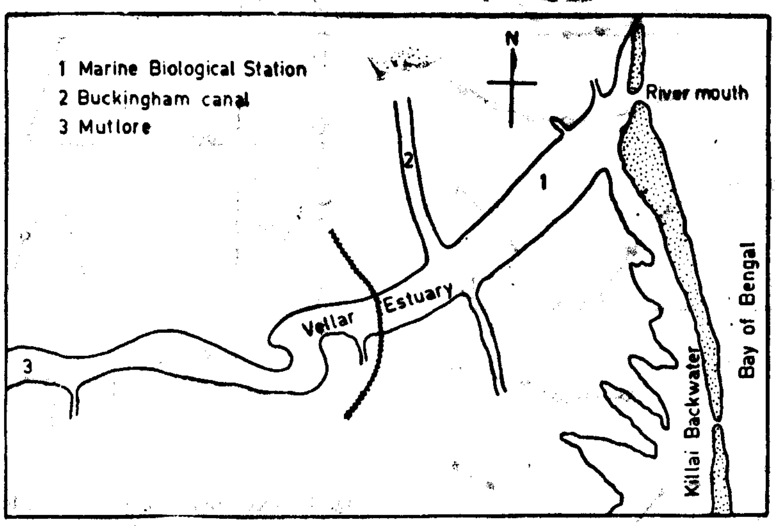

Fig. 1. Map of Vellar Estuary showing station positions.

HYDROGRAPHY

Observation on hydrographical parameters such as salinity, temperature, dissolved oxygen and pH during the seed collections period were made. The surface water temperature ranged between 23.5 and 35.3°C with the maximum in May-June and minimum in December (Fig. 2).

The salinity fluctuated between 0.19 and 36.24‰, the maximum in May-June and minimum in November-December, when the salinity was found to be below 1‰, steadily increasing to attain maximum from April to June (Fig. 2). Dissolved oxygen varied from 3.62 to 8.38 ppm. The pH was in an alkaline range between 7.0 and 8.6.

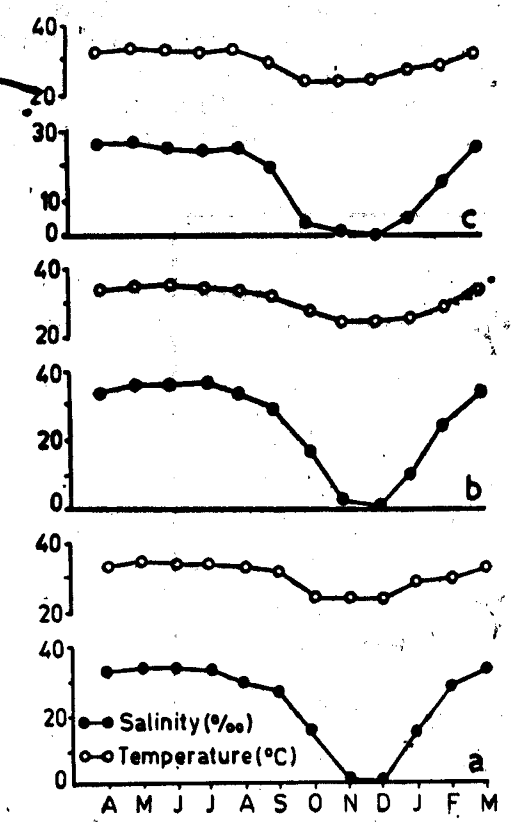

Fig. 2. Seasonal variations in salinity and temperature at three stations in Vellar Estuary : a. Station 1, b. Station 2 and c. Station 3.

Species Composition

Larvae and juveniles of more than seven species of penaeid prawns were recorded in Porto Novo biotopes by Subramaniayam *et al.* (1978). But more attention was given in this paper on fast growing commercial species of prawns viz., *Penaeus indicus*, *P. monodon* and *P. semisulcatus* (Fig. 3 to 5) indicate the seed abundance of prawns in the Vellar Estuary.

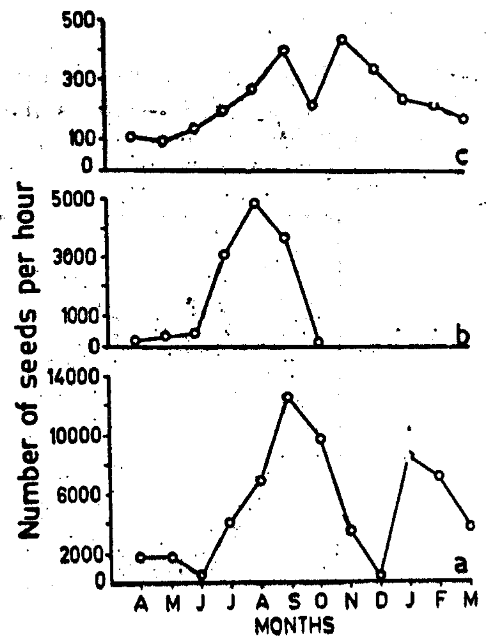

Fig. 3. Occurrence of prawn seeds near the Marine Biological Station at Vellar Estuary : a. *Penaeus indicus*, b. *P. semisulcatus* and c. *P. monodon*.

Penaeus indicus was the commonly available species almost round the year contributing from 80.7 to 86.1% of the total catch in all the three stations. Peak period was in January-March and August-October. Considerable quantities of *P. indicus* were available in the shallow pools of soft soil bottom. The availability of seeds per hour of drag net operation varied from month to month. Minimum numbers of 416, 274 and 240 per hour were collected in December and maximum of 12,504, 8,254 and 8,105 numbers during September respectively from various gradient and tidal zones. The predominant size group ranged between 20 and 40 mm. Identification of

P. indicus postlarvae and juveniles was done in the field by observing a transparent body, black tip of long rostrum and predominant eye ball.

Postlarvae and juveniles of *Penaeus monodon* were available throughout the year in all the three stations and contributing from 3.2 to 12.4% of the total catch. The peak period was found to be September-November and

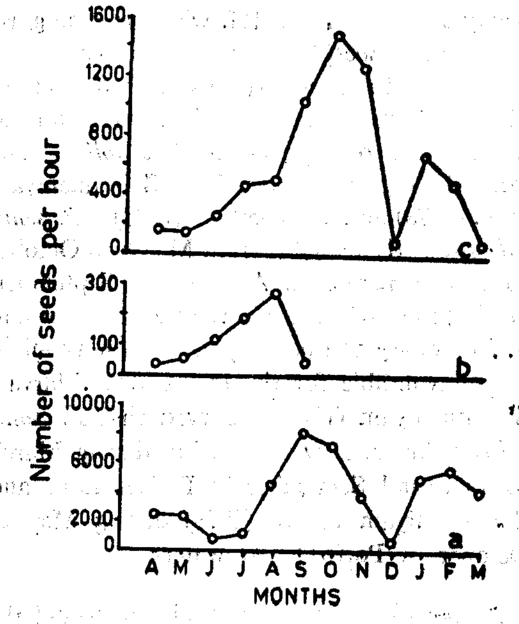

Fig. 4. Occurrence of prawn seeds in Buckingham Canal at Vellar Estuary: a. *Penaeus indicus*, b. *P. semisulcatus* and c. *P. monodon*.

January-February. Considerable numbers of postlarvae and juveniles were available in stations II and III where aquatic weeds, submerged plants, grass, debris and decayed materials were plentiful along the shallow margins. Very few numbers of this seed could be recorded in the non-vegetated place. Collection of seeds of *P. monodon* per hour varied from 8 to 1,481 numbers. Minimum numbers were 53, 50 and 8 in stations I, II and III respectively during December. Maximum numbers, 423 occurred in station I during November, 1,481 in station II during October and 1,181 in station III during February. The predominant size group of 15 to 20 mm could be recorded and the postlarval ingressions were observed more during full moon and new moon periods. Observations showed that *P. monodon* seeds were also clinging on to the weeds, submerged plants and decayed materials, for feeding. Another important characteristic noted

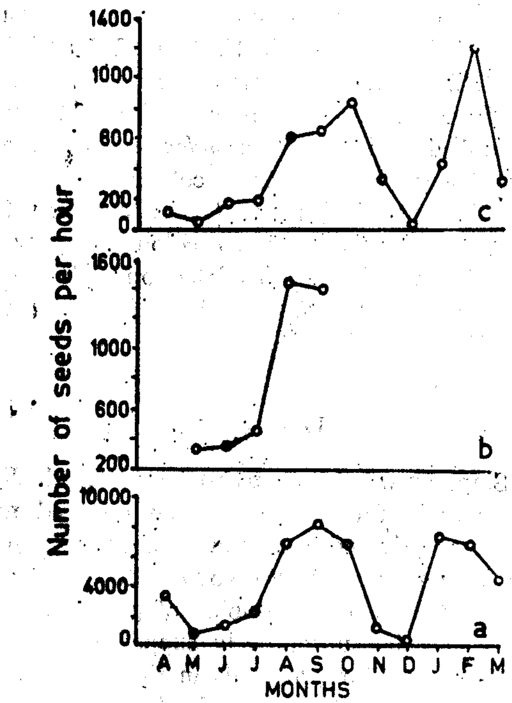

Fig. 5. Occurrence of prawn seeds at Mutlur in Vellar Estuary: a. *Penaeus indicus*, b. *P. semisulcatus* and c. *P. monodon*.

was that *P. monodon* seeds stick on the Velon screen net during collection whereas other species leap here and there. A reddish brown streak appears on the ventral side of the body in the case of postlarvae of *P. monodon*. A thick and dull gray colour band could be found dorsally from the rear end of the rostrum to telson in the later stage. Yellow spot on the base of the pleopods and black and yellow colour bands appear on the body and uropod, in 50 mm and above size. These characters are very useful for collection and segregation of seeds of this species in the field.

Penaeus semisulcatus seeds are available plentifully in the marine grass *Cymadocea isoctifolia*, though scarce in other biotopes. They appeared in the estuary during March, but disappeared in October when the salinity was low. The peak period was August and September when the seed contribution per hour ranged from 128 to 4,724, 19 to 265 and 15 to 1,426 numbers in stations I to III. The predominant size group was 15 to 22 mm. It looked more like *P. monodon* seeds in post-larval stage, but light green colour and shorter length denoted them as *P. semisulcatus*. In later stage, a light green colour band was found on the dorsal side of the body. Because of its green colour it is locally called in Tamil as 'Passi errol'.

Discussion

Since prawn culture technology is gradually growing in India, need for natural seed resources study and management of prawn farms are now greater. Porto Novo biotopes offer a vast potential for developing of prawn farms. This may be substantively supported by the availability of prawn seeds in these brackish-water environments round the year. The seed collection may be carried out by utilising the unemployed and low income group of people available in the surrounding villages. The availability of prawn seeds in abundance justifies the establishment of a prawn seed supply unit here.

Among the three penaeid larvae *P. indicus* was the dominant species followed by *P. semisulcatus* and *P. monodon*. *P. indicus* seeds occurred throughout the year with two peak periods January to March and August to October. The same pattern of abundance and distribution was reported by Subramaniayam and Rao (1968) in Pulicat lake, Rajyalakshmi (1972) in Chilka Lake, Pulicat Lake and Godavari Estuary, by Victor Chandrabose *et al.*, (1978) in Adayar Estuary and by Subramaniyam *et al.*, (1978) in Porto Novo waters. Observations showed that more number of *P. indicus* seeds were available in soft sand of shallow margin with aquatic weeds, as reported by Rajyalakshmi (1972) and Victor Chandrabose *et al.*, (1978). *Penaeus semisulcatus* seeds were available in plenty at station I and III, where marine grass *Cymadocea isoctifolia* and other plants are abundant. In station II very limited quantity of seeds have been collected probably due to the absence of *Cymadocea isoctifolia*. The same finding was reported by Subramaniyam *et al.* (1978) and Gopinathan (1978). *P. semisulcatus* seeds available from March to October with peak period in August and September. During monsoon months they were not found in the estuary and possibly lower salinity might be unfavourable for the ingression of larvae. Subramaniyam (1968) observed that *P. semisulcatus* juveniles were plentiful during March to June and September in Pulicat Lake and Subramaniyam *et al.* (1978) during May to October in Porto Novo waters.

P. monodon seeds were available round the year in all the three stations with two peak periods one in September - November and the other in January - February. More number of *P. monodon* seeds were recorded in station II and III where *Pandanus tectorius* grass (Family *Cyperacea* and *Graminea*) and decayed material were available in plenty in the shallow margins. More or less the same peak period was observed by Victor Chandrabose *et al.* (1978) in Adayar Estuary and Subramaniyam *et al.* (1978) in Porto Novo waters. Gemma Evangeline (1972) and Victor Chandrabose *et al.* (1978) have reported that juveniles of *P. monodon* used to clinging on to the weeds. Present findings also support the above fact.

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Proc. Symp. Coastal Aquaculture, 1982, 1 : 314-320

MASS CULTIVATION OF FOOD ORGANISMS IN HATCHERIES PROBLEMS AND PROPOSED SOLUTIONS

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ABSTRACT

A constant supply of food organisms of suitable size and nutritive value is one of the major problems in hatchery production of seed of cultivable fishes and shell fishes. Though various organisms, unicellular and small invertebrates (mostly copepods) have been found to comprise the diet of these larval stages, only a few (*Artemia salina* and *Brachionus plicatilis*) are commonly used with success in hatcheries. Commercially available *Artemia* nauplii, however, are not always suitable for the small mouth opening of fry, while cultivation of nutritive *B. plicatilis* is laborious and expensive:

In order to diversify the diet in hatcheries, food organisms other than those commonly used are suggested. Special attention is focused on growth of nematodes and copepods. The advantage of nematodes is their small size, fast growth, nutritive value, digestibility as well as tolerance to sea water, after salinity adaptation. Experiments to improve cultivation of marine harpacticoid copepods, resulting in high densities of a few hundred individuals per ml is reported.

INTRODUCTION

PROVIDING suitable food organisms in sufficient quantities is a major problem in the cultivation of early stages of fish and crustaceans. Despite the variety of natural food organisms, only a few have been used in hatcheries. The literature on the cultivation and use of live food has been surveyed by various authors (May, 1970 ; Aronovich and Spektorova, 1971; Kinne, 1977 ; Girin and Person-Le Ruyet 1977 ; Girin, 1979 a, 1979 b, Nash and Kuo, 1975 ; Solangi and Ogle, 1978 ; Sorgeloos, 1980). This paper reviews recent approaches to solving the problem of food organisms for aquaculture.

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DEPENDENCE ON WILD SOURCES

Plankton, a natural food of fish larvae, was used successfully in laboratory rearing (May, 1970 ; Houde, 1978). However, this is an unreliable source for commercial production, due to uncontrollable fluctuations in quality and quantity, and to the drawbacks of collecting methods which do not exclude harmful organisms.

A more reliable method, which was considered by Shelbourne (1964) to be a breakthrough in the rearing of marine fish, is the use of *Artemia* nauplii, hatched, when needed, from cysts. In several fish larvae, *Artemia* nauplii could serve as first food, while with *Mugil capito*, after slowing the nauplii's movement by precooling (Kahan, 1979 b). Recently, G. Sagi, IOLR, Israel, applied this method successfully with *M. capito*, on an enlarged scale. Although *Artemia* cysts can be obtained in the laboratory (Versichele and Sorgeloos, 1980), they are not produced, for economic reasons, on a commercial scale, and therefore the supply of cysts in large quantities is still dependent on collection from natural habitats (Sorgeloos, 1976 ; Sorgeloos *et al.*, 1979). Here, again, wild sources are variable in their nutritive value, according to location and year of collection which greatly affect growth and survival of fish and crustaceans (Beck *et al.*, 1980 ; KleinMacPhee *et al.*, 1980 ; Johns *et al.*, 1980 ; Sandifer and Williams, 1980). These variations have been attributed to changes in chemical composition of strains (Czeczuga, 1980 ; Fujita *et al.*, 1980 ; Schauer *et al.*, 1980 ; Soejima *et al.*, 1980), and are due to genetic variability and/or to the diet of the parents, pollutants (Olney *et al.*, 1980) and cycles of rain and draught (Sorgeloos, 1976).

Cultivation of Food Organisms

Of the variety of organisms eaten by fish larvae in nature, only a few have been cultivated for use in hatcheries. The criteria for suitable candidates are appropriate size, motility, palatability, digestibility, hardiness and high reproductive rate.

Unicellular organisms

Unicellular organisms of different taxonomic groups (algae, protozoa) are ingested by marine fish larvae in nature (May, 1970 ; Kinne, 1977). Few successes in growing marine fish on unicellular organisms alone, i.e., *Gymnodinium splendens* and *Dunaliella*, have been reported (May, 1970 ; Lasker *et al.*, 1970). Nevertheless, many freshwater fish are known to develop exclusively on unicellular organisms (*Paramecium*, *Euglena*, etc.) (Sterba, 1967 ; Masters, 1975 ; Marciak and Bogdan, 1977). Further investigations may increase the use of this source in mariculture too. Various ciliates, i.e., *Fabrea salina*, are considered promising candidates and were used in feeding *Sparus aurata* (Renè, 1979) and *Dicentrarchus labrax* fry (Barnabè, 1976). Unicellular algae such as *Dunaliella*, *Skeletonema*, *Chaetoceros*, *Thalassiosira*, *Nitzchia* and others are known to be good food for larval stages of commercial crustacea (Kinne, 1977 ; Silas and Muthu, 1977) as well as for food organisms such as copepods, rotifers and *Artemia* (Kinne, 1977). In rearing experiments, phytoplankton improved water quality and provided growth factors such as essential fattyacids to the organisms that feed on them, *Artemia* and rotifers (Watanabe *et al.*, 1978, 1979 ; Scott and Middleton, 1979 ; Howell, 1979).

Rotifers

Rotifers were known long ago as food for freshwater fish (Solangi and Ogle, 1978 ; Kawano and Kamel, 1980). Following the successful rearing of the euryhaline rotifer *Brachionus plicatilis* in a sea-water (Ito, 1960) it was introduced into mariculture (Ukawa, 1965 cited by Fujita, 1977). Since then it has become widely used as a food in fish and crustacean hatcheries due to its rapid growth rate (at 24°C, the generation time is 1-3 days), appropriate movement, small size and digestibility. The only limiting factor on rotifer yields is unicellular algae. The addition of algal powder and marine and baker's yeast simplified the mass cultivation of the rotifer (Solangi and Ogle, 1978 ; Al-Khars *et al.*, 1980 ; Kawano and Kamel, 1980). Gatesoupe and Luquet (1981) have developed a new, effective mixture of dry feed for growth of rotifers. Some innovations which facilitate cultivation have recently been employed in growing *Brachionus* (Pitt, 1979 ; Rothbard, 1979 ; Trotta, 1981). Lybzens *et al.*, (1980) reported a simple method of inducing *Brachionus* females to produce resting eggs, by transferring them to 25% sea water. This could provide a way of storing rotifers to be used when needed. The importance of unicellular algae to the nutritional quality of rotifers is referred to in the previous paragraph — unicellular organisms.

Copepods

Copepods are of great ecological significance and serve as a major food source for numerous organisms including fish and crustaceans (Kinne, 1977; Goswami, 1977; Goswami *et al.*, 1977; Silas and Muthu, 1977; James and Thirunavukkarasu, 1980). Copepods were grown successfully by using various dietary substitutes for algae (Kitajima, 1973; Gopalan, 1977; Ikeda, 1973; Rothbard, 1976; Kinne, 1977; James and Thompson, 1980). One kg of *Tigriopus japonicus* could be harvested every day for two weeks, when grown in 50 to 200-ton tanks at densities of 2-5 individuals/ml (Fujita, 1977). Recently, higher yields of 2 kg were obtained daily for a longer period (Anraku, Per. Comm.). By using market vegetables or wheat bran, higher densities were achieved with several other species (*Tisbe holothuriae, Amphiascella subdebilis, Nitocra spinipes* and *Micrestris elatensis*), in containers of 50 ml and 2.5 litres (Kahan, 1979 a, 1981; Kahan and Azoury, 1981). Lately, densities of 300 individuals per ml and more and a population doubling time of 3-7 days were obtained (Kahan, 1981).

It is not yet clear whether the vegetables alone are responsible for the good growth of the copepods, or whether their nutritive value is supplemented by the microorganisms that develop on them (Provasoli *et al.*, 1959; Rieper, 1978; Sumitra-Vijayaraghavan and Ramadhas, 1980).

Nematodes

Nematodes have been used successfully in the rearing of aquarian and commercial freshwater fish (common and silver carp) (Kahan and Appel, 1975; Kahan *et al.*, 1970). The above fish can digest the hard cuticle of *Panagrellus* nematodes (Kahan *et al.*, 1980) as can 2-week old *Mugil capito* (Kahan, 1979 b) and 3-week old *Sparus aurata* (unpublished). The crustaceans *Crangon* (Gerlach and Schrage, 1969) *Penaeus* (Samocha and Levinsohn, 1977 and *Macrobrachium rosenbergii* (unpublished) ingest *Panagrellus* and might use them too, as a supplementary live food. Recently, Dr. Y. Ahamine from Marifarm Inc., Panama City, Florida, U.S.A., produced 30 million penaeid postlarvae after feeding them only on algae, rotifers and *Panagrellus redivivus* nematodes. The survival rate was 50-96%.

Nematodes can be grown easily in masses, are small, and can withstand seawater salinity for several hours, as was found in *Panagrellus* (Kahan and Appel, 1976) and *Caenorhabditis elegans* (unpublished). Non-marine organisms, of other taxonomic groups which can withstand seawater, such as *Enchytraeus albidus* and Chironomids (Ivleva, 1969), Turbellaria (Shirgur, 1980) Cladocera (Naik and Shirgur, 1980 a, b, c; Ghosh and Kowtal, 1980) and Tanaidacea (Gopalan *et al.*, 1980) could also be used in mariculture.

Larvae of marine invertebrates (Annelida, Mollusca, Echinodermata)

Members of this category are cultivated commercially themselves and their larvae could be used as food organisms for fish whenever spawning seasons of both fish and invertebrate larvae coincide (Kinne, 1977).

NON-LIVING DIETS (FRESH, FROZEN AND ARTIFICIAL)

Attempts to reduce dependence of fish and crustacean larvae rearing on an exclusively live diet have gained some progress, recently, by introducing fresh, frozen and artificial diets. Fresh crushed, filtered crustaceans (*Squilla*) have been used successfully in feeding experiments with crustaceans (Alkunhi, per. comm.) Frozen and artificial diets were used in early weaning techniques (Girin, 1979 a, b; Goswami, 1977; Dye, 1980; Brasola *et al.*, 1979; Mock *et al.*, 1980; Manzi and Maddox, 1980).

Feeding experiments with *Dicentrarchus labrax* (Kentouri, 1978) and *Diplodus sargus* (Kentouri *et al.*, 1980) show that the fish larvae could grow after learning to ingest defrosted plankton (rotifers, copepods and *Daphina*) which are circulated in the rearing tanks. Although growth on a frozen diet was slower than on live food, there was no apparent effect on survival (Kentouri, 1978). It was necessary, however, to add defrosted food periodically as the fry avoided the plankton 2-4 hours after defrosting, due to its deterioration (Kentouri, 1978). The development of plankton collecting pumps and a timing device for defrosting the plankton in the rearing tank has already been undertaken (Divanach, per. comm.).

It is not yet known why live food organisms are superior to other foods (Van der Wind, 1979). Possible reasons are that living organisms are ingested more readily (Kinne, 1977) and digested more easily (Jirasek *et al.*, 1977) and have essential growth factors, such as vitamins and polyunsaturated fattyacids, which are absent in non-living food. Verification of these possibilities could contribute to progress in mariculture.

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RELATIVE EFFICIENCIES OF PELLETIZED FEEDS COMPOUNDED WITH DIFFERENT ANIMAL PROTEINS AND THE EFFECT OF PROTEIN LEVEL ON THE GROWTH OF THE PRAWN *PENAEUS INDICUS*

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ABSTRACT

Laboratory experiments with four pelletized feeds, compounded separately with the animal proteins from prawn waste meal, mantis shrimp protein, clam meat powder and fish meal in combination with the plant protein from groundnut cake, were conducted to study the relative efficiency by feeding juvenile *Penaeus indicus*. The animal and the vegetable proteins in each feed were approximately adjusted in the ratio 1 : 1. Tapioca powder was used as the source of carbohydrate as well as the binding agent. The control experiment was carried out with the feed prepared solely from fresh clam meat. Feeds with mantis shrimp protein and clam meat powder gave high increase in live weight and good food conversion values followed by the feeds with fresh clam meat, prawn waste meal and fish meal.

Feeding experiments with pelletized feeds, consisting of mantis shrimp protein, groundnut cake and tapioca powder with crude protein content ranging from 20.5% to 46.5% were conducted on the juvenile *P. indicus*. Progressive increase in the live weight gain was recorded with the increase in the crude protein level upto 42.9% and declined thereafter, while the protein efficiency ratio was the highest at 20.5% crude protein level.

INTRODUCTION

THE white prawn *Penaeus indicus* has been identified as one of the most suitable species for intensive culture in coastal aquaculture practices. The development of a suitable feed is an important pre-requisite for the successful culture operations. For that the basic knowledge on the nutritional requirements of the prawn is essential. Commendable work has been done in this direction (New, 1978) and a number of feeds have been patented in various countries of the world. Very often these feed formulations cannot be directly utilized due to either the non-availability of the raw materials or their prohibitive cost.

Protein forms the most important constituent in prawn nutrition. Several workers have conducted studies on the protein requirement of different species (Deshimaru and Shigeno, 1972 : Sick *et al.*, 1972; Venkataramaiah *et al.*, 1975 ; Balazs and Ross, 1975 ; Colvin, 1976).

In the present study, an attempt has been made to study the relative efficiencies of some of the locally available animal protein materials to be included in prawn diets and the protein requirement in the feeds in terms of the raw materials for the culture of *P. indicus*.

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MATERIALS AND METHODS

Raw materials

The prawn waste includes head and exoskeleton obtained from the peeling sheds. Mantis shrimp protein was prepared from *Oratosquilla nepa*. The wet material was boiled in water and the coagulated protein was separated and dried (Garg *et al.*, 1977). This material was obtained from the Central Institute of Fisheries Technology, Cochin. The clam (*Vellorita cyprenoidea*) meat was separated from the shells by heating and the whole meat was dried. Fish meal was obtained from the Kerala Fisheries Corporation, Azhikode. Groundnut cake and Tapioca (*Manihot utilissima*) were procured from the local market. All the raw materials were dried in an oven at 70-80°C and ground in an electrical grinder and sieved through 60 mesh sieve. Fresh clam meat (*Sunneta scripta*, 82% moisture), stored in the deep freeze, was given as the control diet.

The crude protein contents of the raw materials, determined by the micro Kjeldahl method, are given in Table 1.

Preparation of the experimental feeds

In each feed the animal and the plant proteins were approximately adjusted in the ratio 1:1. Groundnut cake was the common plant protein source in all the feeds. Tapioca powder was used as the main source of carbohydrate as well as the binding agent. Calcium lactate and potassium dihydrogen phosphate and multivitamins were included in all feeds.

Tapioca powder was first cooked with 40-50% of water for 10-15 minutes until the starch gelatinised. The other premixed ingredients were added to the paste and thoroughly mixed into a dough. The dough was passed through a 3 mm diameter die in a screw press. The pellets were dried at 70-80°C and found to be quite water stable.

Rearing

The juveniles of *Penaeus indicus*, used in the feeding experiments were collected from the backwater canals around the Vypeen Island. The animals were acclimatized for 5-7 days and starved for one day before the start of the experiment.

Feeding experiments were conducted in 50 litre capacity circular plastic troughs. Ten animals were stocked in each trough. The troughs were covered with velon screens to prevent the animals from jumping out. The sediments were removed regularly and the water was changed once in three days. Aeration was provided with an air compressor.

Feeding was done at the rate of 10-15% of the live body weight once in a day in the evening hours in petri dishes kept at the bottom in the middle of the trough. The food left

TABLE 1. *Crude protein values of the raw materials*

Ingredients	Prawn waste meal	Mantis shrimp protein	Clam meat powder	Fish meal	Groundnut cake	Tapioca
Crude protein content. % on dry basis ..	35.2	59.2	48.1	60.7	48.5	2.0

over was recovered every day before feeding. Weight and measurements were taken every ten days. No attempts were made to control the environmental conditions.

Feeding experiment I

Four experimental feeds 1, 2, 3 and 4 were compounded separately with the animal proteins from prawn waste meal, mantis shrimp protein, clam meat powder and fish meal in combination with the common plant protein from groundnut cake. The ingredients in each feed were adjusted to give the same crude protein content of 35%. The percentage composition of the feeds is given in Table 2.

Prawns with an average body weight of 100 mg were separately fed with feeds 1-4 and fresh clam meat for 30 days. For each feed two sets of experiments were run concurrently.

The salinity of the water increased from 1.8‰ to 7.5‰. The temperature ranged between 28.5°C to 32.5°C and the pH between 8.0 and 8.7.

The results of the feeding experiments are given in Table 3.

TABLE 2. *Percentage composition and crude protein values of the experimental feeds* 1-4

Ingredients %	Experimental feeds 1	2	3	4
Groundnut cake	35.0	38.0	40.0	35.0
Tapioca powder	17.0	31.0	19.0	37.0
Prawn waste meal	45.0	—	—	—
Mantis shrimp protein	—	28.0	—	—
Clam meat powder	—	—	38.0	—
Fish meal	—	—	—	25.0
Mineral mix*	2.0	2.0	2.0	2.0
Vitamin mix**	1.0	1.0	1.0	1.0
Total	100.0	100.0	100.0	100.0
Crude protein %	34.4	35.0	33.3	33.9

* Mineral mix : Each kg of the feed contains Calcium lactate 14 g ; Potassium dihyrogen phosphate 8g ; Ferrous sulphate 106 mg, Magnesium phosphate 480 mg.

** Vitamin mix Each kg of the feed contains vitamin A 40000 I.U., Thiamin mononitrate 100 mg, Riboflavin 20 mg, Nicotinamide 100 mg, Cynocobalamine 10 mg, Ascorbic acid 50 mg, Calciferol 4000 I.U., vitamin E 15 mg, Biotin 0.5 mg.

TABLE 3. *Results of the feeding experiment* 1 *fed with the feeds* 1-4 *and fresh clam meat for* 30 *days*

Description	Experimental feeds 1	2	3	4	Fresh clam meat
Initial average body weight (mg)	100	100	100	100	100
Final average body weight (mg)	380	513	497	250	400
Increase in average body weight (mg)	280	413	397	150	300
Percentage increase in average body weight	280	413	397	150	300
Average growth (mg/day)	9.30	13.80	13.20	5.00	10.00
Total food consumed (g)	6.38	5.16	5.79	5.62	—
Average food ingestion (mg/animal/day)	21.30	23.60	19.30	21.00	—
Food conversion*	2.27	1.71	1.46	4.20	—
Survival %	100	80	100	70	30

* Food conversion : $\frac{\text{Average rate of food ingestion}}{\text{Average growth rate.}}$

Feeding experiment 2

Experimental feeds 5, 6, 7, 8 and 9 were prepared consisting of mantis shrimp protein, groundnut cake and tapioca powder with the crude protein contents of 20.6, 28.5, 35.0, 42.9 and 46.5% respectively. The percentage composition of the feeds 5-9 is presented in Table 4.

TABLE 4. *Percentage composition and crude protein values of the experimental feeds 5-9*

Ingredients	Experimental feeds				
	5	6	7	8	9
Mantis shrimp protein	14.0	21.0	28.0	35.0	42.0
Ground nut cake	19.0	28.5	38.0	47.5	57.0
Tapioca powder	64.0	47.5	31.0	14.5	10.0
Mineral mix	2.0	2.0	2.0	2.0	2.0
Vitamin mix	1.0	1.0	1.0	1.0	1.0
Total	100.0	100.0	100.0	100.0	112.0
Crude protein %	20.6	28.5	35.0	42.9	46.5

The animals with an average body weight of 200-230 mg were fed separately with feeds 5-9 for 30 days. For each feed three sets of experiments were run concurrently.

The salinity of the water used in the experiment ranged from 17.3‰ to 20.3‰, temperature varied between 30.8 to 32.5°C and pH between 7.9 and 8.0. The results are presented in Table 5.

RESULTS

In the first experiment, feeds 2 and 3 with mantis shrimp protein and clam powder topped among the protein materials tested, by producing an average weight increase of 313% and 297% and an average growth of 13.8 and 13.2 mg/day respectively (Table 3). These were followed by fresh clam meat (200% and 10 mg/day), feed 1 with prawn waste (181% and 9.3 mg/day) and feed 4 with fish meal (50% and 5 mg/day). Clam powder gave the best food conversion (1.46) followed by mantis shrimp protein (1.71), prawn waste (2.27) and fish meal (4.2). The food conversion in the case of fresh clam meat was not determined, as there was heavy mortality.

The average rate of food ingestion was the highest in the case of mantis shrimp protein (23.6 mg/day/animal) and the lowest in the

TABLE 5. *Results of the feeding experiment 2 fed with the feeds 5-9 for 30 days*

Description	Experimental feeds				
	5	6	7	8	9
Initial average body weight (mg)	210	200	230	200	200
Final average body weight (mg)	590	590	700	890	800
Increase in average body weight (mg)	380	390	470	690	600
Percentage increase in average body Weight	181	195	204	345	300
Average growth (mg/day)	12.70	13.00	15.70	23.00	20.00
Total food consumed (g)	8.66	7.05	8.97	8.88	8.77
Average rate of food ingestion (mg/animal/day)	28.90	23.50	29.90	29.60	29.20
Food conversion	2.28	1.80	1.90	1.29	1.46
Protein efficiency ratio*	2.10	1.96	1.50	1.50	1.18
Survival %	100	100	100	100	100

* Protein efficiency ratio : Live weight gain per gram of protein consumed.

case of claim powder (19.3 mg/day/animal), while for prawn waste and fish meal the food intake was 21.3 and 21.0 mg/day/animal respectively.

Weight gain increased with time (Fig. 1) in general. The increase in weight was the highest in the last ten days and lowest in the

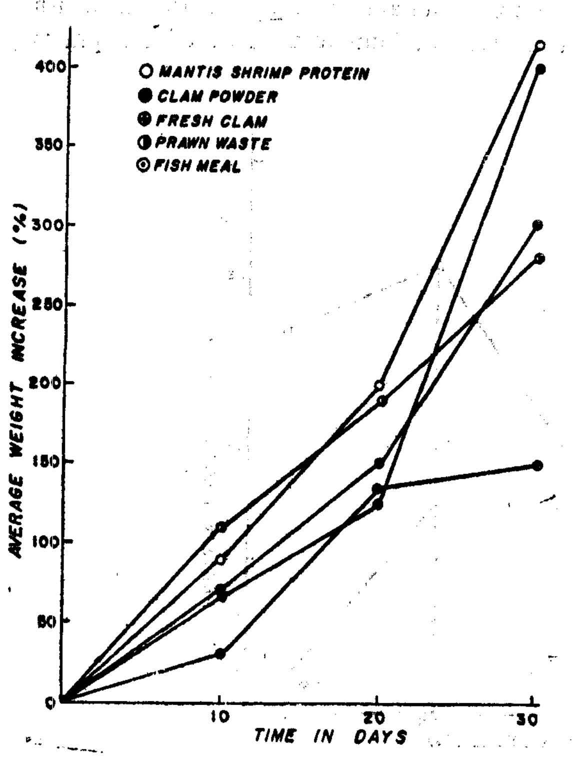

Fig. 1. Growth curves of the prawn *P. indicus* fed on he feeds compounded separately with prawn waste, mantis shrimp protein, clam meat powder, fish meal and fresh clam meat.

first ten days in the case of feeds 2, 3 and fresh clam meat, whereas in the case of feeds 1 to 4 it was vice versa. In the case of fresh clam meat frequent moulting, heavy mortality and cannibalism were observed.

In general the animals were immediately attracted to all the foods. However, the preference was observed for prawn waste, mantis shrimp protein, fresh clam meat, clam powder and fish meal in the decreasing order.

The gain in live-weight increased with the increase in crude protein level in the diet upto 42.9% (Table 5) and declined thereafter in the second experiment. The feed with 42.9% crude protein gave the highest increase in live weight gain (345% and 23 mg/day) and best food conversion (1.29). The protein efficiency ratio declined gradually with successive increase in the dietary protein level.

There was a sharp increase in weight between 35.0 and 42.9% crude protein levels, while the increase in weight from 20.6 to 35.0% protein levels was gradual (Fig. 2, curve A) and again there was a gradual decline between 42.9 and 46.5% protein. The protein utilisation gradually declined from 20.6 to 35.0 crude protein level (Fig. 2, curve B); it was steady between 35.0 and 42.9% and it sharply declined between 42.9 and 46.5%.

DISCUSSION

Mantis shrimp protein and clam powder gave almost identical growth rates, while clam powder gave better food conversion. But both are superior to fresh clam meat. The growth obtained by prawn waste is comparable to that of the fresh clam meat. Venkataramaiah *et al.* (1978) observed that *Penaeus aztecus* fed with shrimp waste pellets gave good results. Sandifer and Joseph (1976) found waste shrimp heads (*P. setiferus*) were a good source of fatty acids and pigments in the diets for *Macrobrachium rosenbergii*. Similar results were obtained by Forster and Beard (1973) for *Palemon serratus*. Prawn waste protein is reported to be having several essential amino acids (Foster, 1975). Fresh clam meat failed to give superior growth results compared to that of the compounded diets with mantis shrimp protein and clam powder. Kanazawa *et al.* (1970) reported that the fresh diet of short-necked clam (*Tapes philippinarum*) gave superior growth compared to the compounded diets for *Penaeus japonicus*. Similar results were obtained by Forster and Beard (1973) for *Palaemon serratus*. But Venkataramaiah *et al.* (1975) found that although the live foods such as *Artemia* nauplii and shrimp meat gave superior growth in brown shrimp, a high rate of chitinoclastic bacterial infection, leading to ing. The probable factor may be the iodine rich thyro-proteins in the fresh clam (Personal discussion with Kai W. Chow, Aquaculture Department and Co-ordination Prog., FAO).

Fish meal gave comparatively poor results as reported earlier by Deshimaru and Shigeno (1972) and Colvin (1976). The former workers found that the amino acid composition of fish meal was not similar to that of the prawn

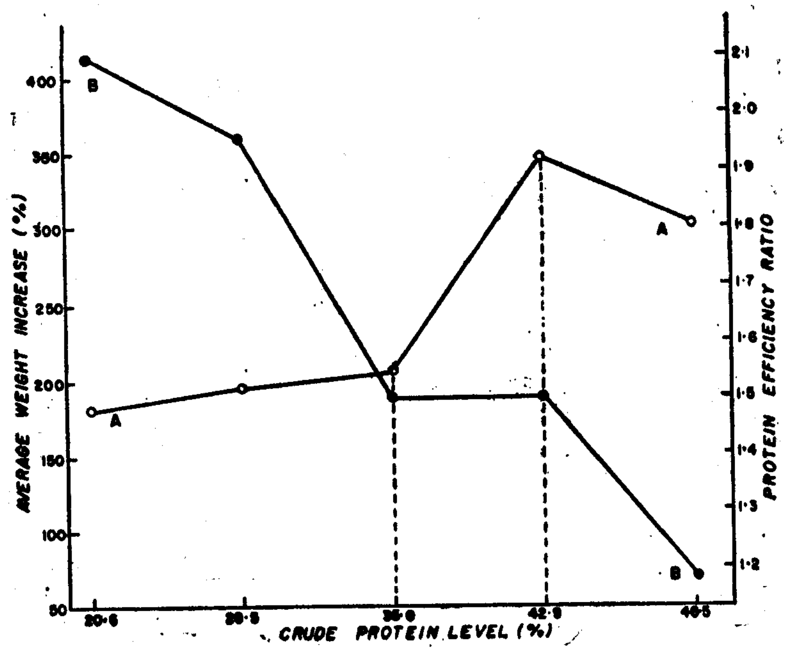

Fig. 2. Growth, dietary protein level and protein efficiency ratio curves of the prawn *P. indicus*: A. Relationship between the dietary protein level and live-weight increase and B. Relationship between dietary protein level and protein efficiency ratio.

heavy mortality was observed in these experiments. The relatively poor performance obtained by the fresh clam meat in the present study may be due to similar reasons.

Frequent moulting was observed during feeding experiments with fresh clam meat suggesting that this contains a factor which induces moult-

P. japonicus. The latter suggested that the relative deficiency of the amino acids, tyrosine and phenylalanine in the fish meal may be the reason for its relatively poor performance.

Prawns were observed to prefer prawn waste. The odour it possesses may be attracting the animals and making the feed more palatable, The protein quality of the prawn waste may be further improved by blending it with other high quality protein materials such as mantis shrimp, in suitable proportions.

Deshimaru and Shigeno (1972) observed that the growth of *P. japonicus* was found to correlate with the amount of crude protein in the diet. A similar trend was observed by Balazs and Ross (1976) that high protein content produced larger prawns (*M. rosenbergii*). Venkataramaiah *et al.*, (1975) found best growth with the food containing 40% protein (*P. aztecus*) and Colvin (1976) recorded highest live-weight gain with a 43% protein diet (*P. indicus*). The findings of experiments carried out in the present study conform to the above results. The growth values recorded in the present study (23 mg/day with initial weight 0.2 g) are comparable to that of Colvin (1976, 44 mg/day with initial weight 0.95) taking into consideration the initial mean weights of the prawns. The food conversion values obtained are comparatively superior.

The optimum protein level in the diets for penaeid prawns appears to be between 35 and 40%. This is indicated by the steep rise in weight increase (Fig. 2, curve A) between 35.0 and 42.9%, while the increase in weight was gradual in the lower protein levels. This is further supported by the fact that the protein utilisation is steady (Fig. 2, curve B) between the two protein levels. Results from other workers confirm that protein levels compatible with maximum or near-maximum growth were between 30 and 40% for penaeid prawns (Sick *et al.*, 1978 ; Forster and Beard, 1973 ; Venkataramaiah *et al.*, 1975). In general it is observed that the high protein levels in the diet beyond the optimum level do not produce significant increase in growth or the growth is not proportional to the increase in protein level. The probable explanation for this may be that the increase in protein decreases the quantity of other energy giving nutrients such as fat and carbohydrate in the diet, from which the animals normally derive most of the energy required for their metabolic activities. In that case the protein in excess of the optimum level is mostly utilised for the metabolic energy required and not for tissue growth. This is indirectly supported by the fact that the protein utilisation, in terms of live-weight gain, declines with the increase in the dietary protein level. However, this needs further study to establish the fact.

The results of the present study indicate that the quality of the protein in the diets depends upon its source and influences the growth. This is in accordance with the findings of Forster (1975). Therefore for the practical utilization, it will be more realistic to select the suitable raw materials available in the region concerned and find the nutritional requirements in terms of the raw materials, instead of purified protein materials, such as casein. For the growth and food conversion obtained by the diets containing casein at a particular protein level may be entirely different from that of the diets containing the selected raw materials depending upon their protein quality.

The results of the present study show that the mantis shrimp protein is one of the high quality animal protein sources for diets. Little Information is available in the literature about the use of mantis shrimp in prawn diets. Considerable quantities of mantis shrimp are landed along with the prawns. But most of it is not properly utilised. The utilisation of mantis shrimp as one of the prawn feed ingredients may be a promising proposition.

Conclusion

Mantis shrimp protein and dry clam powder may be considered high quality animal protein sources to be used in the prawn diets. Prawn waste provides desirable flavour and palatability in the diets for prawns. Fresh clam meat contains a factor which induces moulting in the juvenile prawns. Fish meal alone may be a relatively poor animal protein source for prawns. Maximum growth rate is obtained with diets containing 42.9% crude protein and the optimum protein level in the diets for penaeid prawns lies between 35-40%.

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NUTRITIVE EVALUATION, TRACE METALS AS WELL AS PERSISTENT PESTICIDES CONTENT IN SHRIMP PASTE PRODUCED IN THE STATE OF PENANG, MALAYSIA

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Abstract

Investigations on the nutritive values, trace metals, PCBs and pesticides contamination in 19 shrimp pastes, *viz.*, belacan ; the local product of solid paste, cencaluk ; the local product of liquid paste, produced by various companies in the State of Penang indicated the following.

From the nutritive point of view the moisture, crude protein, crude lipids and ash contents varied between a range of 28.6-70.7%, 32.7-56.6%, 2.77-6.48% and 25.5-57.6% respectively. High levels of Ca 11,300-27,400 ppm, K 4,300-12,800 ppm, Mg 1,400-5,100 ppm, Na 20,700-96,300 ppm and P 8,000-14,700 ppm were also detected.

With regards to trace metals content of Cd, Co, Cr, Cu, Fe, Hg, Mn, Ni, Pb, and Zn the elements of Cd, Co, Cr, Ni and Pb were below detectable levels (BDL) while Cu, Fe, Hg, Mn and Zn ranged between 5.8-22, 82-540, BDL-0.073, 6.9-35 and 36-75 ppms respectively.

PCBs and p,p'DDE contents in the shrimp pastes ranged between non-detectable level (ND)-0.046 ppm and ND-0.0195 ppm, respectively.

Based on the forementioned results, it is noticeable that the solid and liquid shrimp pastes produced locally in the State of Penang are of high nutritive value and is barely contaminated by contaminants of trace metals, PCBs or persistent pesticides which might culminate in health hazards.

Introduction

Shrimp paste, commonly known as belacan (solid paste) and cencaluk (liquid paste) are essentially fermented small shrimps products of Mysid shrimps (udang baring, udang geragok) manufactured extensively throughout South East Asia. In Malaysia, the State of Penang is the major producing state, although production has had a decreasing tendency (Gunn Chit Thye, 1979).

Production of solid shrimp paste is normally done in the following manner. Mysid shrimps caught in fine meshed nets along the coastal waters are initially salted between 6-8%, depending on the seasons and dried on mats in the sun for *ca*. 5-8 hours. During this drying process, all foreign contaminating material are removed.

The partially dried shrimps are then minced and packed tightly in wooden tubs to undergo a

TABLE 1. *Nutritive evaluation, minerals and trace metals content in solid and liquid shrimp pastes (belachan and cencaluk) produced in the state of Penang. The trace metals Cd, Co, Cr, N and Pb were below detectable level (BDL) in all solid and liquid shrimp pastes*

Factory location & Manufacturer	Production/ month (Kg)	Market	Moisture (%)	Crude Protein (%)	Crude Lipids (%)	Ash (%)
TANJONG TOKONG						
Kim Bian Leong Belachan Factory	3333	Hong Kong & Singapore	32.3	52.3	4.72	29.9
Tan Siew Sim Cencaluk Factory	445	Penang	67.5	37.2	4.48	42.1
Lim Sek Har Belachan Factory	2222	Singapore & Kuala Lumpur	35.0	46.6	4.11	28.5
BATU FERRINGHI						
Ban Joo Lee Belachan Factory	2222	Kuala Lumpur	32.8	51.3	5.50	33.0
Goh Ah Sim Cencaluk Factory	278	Penang	70.7	39.3	3.83	38.9
Sim Seng Lee Belachan Factory	4443	Aust., Iran, Singapore & Indonesia	35.0	49.5	5.20	35.0
BALIK PULAU						
Guan Seng Huat Belachan Factory	2222	Penang	33.1	49.0	4.90	32.7
Hock Lee Belachan Factory	2222	Singapore Hong Kong & Alor Setar	32.6	52.6	6.14	28.1
Kim Hoa Belachan Factory	2777	Hong Kong & Singapore	28.6	50.8	5.21	34.1
Razali Mohd. Arif Belachan Factory	1666	Kedah, Perak & Kuala Lumpur	40.1	51.8	6.22	29.1
Wah Hup Belachan Factory	2777	Hong Kong & Singapore	34.6	47.3	4.89	32.0
Kuda Laut Brand Cencaluk Factory	8331	Japan	60.0	32.7	2.77	57.6
TELOK KUMBAR						
Kassim Yusof Belachan Factory	1111	Kedah & Penang	33.3	49.8	6.48	30.7
Shafie Awang Belachan Factory	3333	Kuala Lumpur, Singapore & Indonesia	37.1	38.2	4.63	43.5
Sim Hock Seng Belachan Factory	2777	Singapore & Indonesia	43.4	47.8	4.53	36.3
TELOK TEMPOYAK						
Hassan b. Tahir Belachan Factory	1111	Kedah, Perlis & Penang	41.5	54.2	5.80	31.5
Hashim b. Ayob Belachan Factory	556	Kedah, Perlis & Penang	44.6	44.3	4.68	35.1
Mohd. Noor Belachan Factory	556	Kedah	39.3	46.7	4.62	37.6
PULAU AMAN						
Norbed b. Yusof Malay Belachan Factory	—	—	38.1	56.6	5.50	25.5

Ca	K	Mg	Na	P (μg/gm dry weight)	Cu	Fe	Hg	Mn	Zn
27,400	6,300	5,100	26,100	13,900	13	260	0.025	13	62
14,900	5,500	3,000	44,200	10,600	18	170	BDL	14	50
26,700	7,900	4,100	30,000	12,500	17	220	BDL	10	53
22,100	9,300	3,700	35,200	12,900	22	240	BDL	11	63
18,500	12,500	3,200	40,600	11,500	17	180	BDL	26	55
23,200	5,000	3,200	46,700	12,000	12	340	BDL	15	40
25,200	9,400	3,300	30,700	14,600	11	110	BDL	35	75
21,700	9,600	3,200	22,800	13,300	15	190	BDL	24	58
23,900	5,500	3,200	25,500	13,200	11	250	0.02	17	55
2,100	8,900	2,000	33,900	13,000	11	240	BDL	12	36
24,500	11,300	3,000	35,200	13,100	10	100	BDL	13	62
11,300	11,000	1,800	96,300	8,000	14	82	0.073	6.9	37
22,800	9,200	2,000	37,100	12,000	11	300	0.021	9.7	50
21,500	4,300	4,000	42,100	12,300	14	540	0.073	16	48
18,200	8,500	3,200	35,900	12,300	11	140	BDL	14	56
20,100	7,700	1,400	34,200	13,000	12	260	0.023	10	61
23,200	7,400	3,700	31,600	14,700	16	430	BDL	16	56
22,900	8,200	4,100	37,700	12,000	15	340	BDL	18	58
25,100	12,800	3,500	20,700	14,000	5.8	110	BDL	12	62

curing process of *ca.* 7-14 days. Packing the minced shrimps in tubs is done with utmost care objectively to avoid air-pockets which might lead to the deterioration and discolouring of the final product. After the lapse of the first curing period, a second mincing process is performed and the product cured for another period of *ca.* 1 month. The second cured product is then dried, minced and packed as solid paste.

With regards to liquid shrimp paste, it is just the simple process of preserving mysid shrimps in 6-7% brine and other minor additives which vary from company to company.

Both belacan and cencaluk been essential ingredients in the diet of Malaysians, the authors have endeavoured to evaluate the nutritive values of 19 different products from the State of Penang and determine the extent of pollutants, *viz.* the ten different trace metals, PCBs and persistent pesticides, existent in them from the viewpoint of health. This study will substantiate itself in relation to pollution studies by CAP (1976), Lee and Loh (1976) and the authors (1979).

The authors wish to express their deepest gratitude to the School of Biological Sciences, University Sains Malaysia, Penang, Malaysia and the Department of Marine Environmental Technology, Tokyo University of Fisheries, Tokyo, Japan for all the aid rendered during the course of this study.

Materials and Methods

Experimental samples of belacan and cencaluk were obtained fresh from 19 companies located in six areas, *viz.*, Tanjong Tokong, Batu Ferringhi, Balik Pulau, Telok Kumbar, Telok Tempoyak and Pulau Aman, in the State of Penang, Malaysia (Fig. 1).

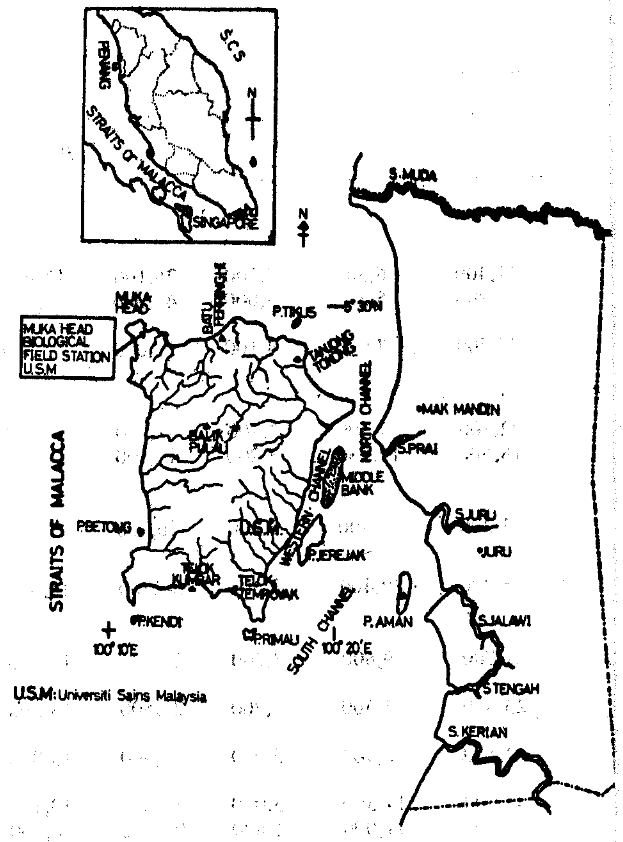

Fig. 1. Map showing the various areas where shrimp paste is manufactured in the State of Penang, Malaysia.

Crude protein content analysis of the samples was performed using the microkjeldahl method while lipids by the Soxhlet method.

Ash content of samples was determined by heating known amounts of dried samples at 450°C for approximately 24 hours followed by repetitions of weighing for a number of times after intermitent dessication until constancy in weight was obtained.

The ions of Ca, K, Mg and Na and trace metals of Cd, Co, Cr, Cu, Fe, Mn, Ni, Pb and Zn in belacan and cencaluk samples were determined using an atomic absorption spectrophotometer (Varian Techtron AA 120) on predigestion overnight of 0.5 gm of sample in a 10 ml mixture solution of perchloric : nitric acid (1:2) and high heating over an electrothermal heater until white fumes appeared. This digest was then diluted appropriately and values obtained through atomic absorption spectrophotometry were expressed as $\mu g/gm$ dry weight of samples. With the same digest, P content was determined using the method of Strickland and Parson (1968).

In the case of Hg content it was calibrated using a Coleman Mercury Analyzer MAS 50 according to the method of Stanley *et al.*, (1971).

PCBs and persistent pesticides contents in the belacan and cencaluk samples were determined after processing the samples as shown in Appendix I at the end of this paper.

RESULTS

The nutritive values of the various shrimp pastes and their contents of trace metals are shown in Table 1. It is noticeable that their moisture, crude protein, lipids and ash contents vary from 28.6-44.6%, 38.2-56.6%, 4.53-6.48% and 25.5-43.5% for belacan and

TABLE 2. *PCBs and DDE contents in solid and liquid shrimp paste (belachan and cencaluk) produced in the state of Penang*

Factory Location & Manufacturer	PCBs (KC 400) (μg/g dry weight)	DDE
TANJONG TOKONG		
Kim Bian Leong Belachan Factory	0.013	0.0005
Tan Siew Sim Cencaluk Factory	0.034	0.0045
Lim Sek Har Belachan Factory	0.032	ND*
BATU FERRINGHI		
Ban Joo Lee Belachan Factory	0.034	0.0029
Goh Ah Sim Cencaluk Factory	0.033	ND*
Sim Seng Lee Belachan Factory	0.035	0.0084
BALIK PULAU		
Guan Seng Huat Belachan Factory	0.021	0.0057
Hock Lee Belachan Factory	0.023	0.0034
Kim Hoa Belachan Factory	0.030	0.0189
Razak Mohd. Arif Belachan Factory	0.016	0.0032
Wah Hup Belachan Factory	0.023	0.0060
Kuda Laut Brand Cencaluk Factory	0.038	0.0045
TELOK KUMBAR		
Kasim Yusof Belachan Factory	0.022	0.0043
Shafie Awang Belachan Factory	0.032	0.0169
Sim Hock Seng Belachan Factory	0.018	0.0123
TELOK TEMPOYAK		
Hassan b. Tahir Belachan Factory	ND*	0.0026
Hashim b. Ayob Belachan Factory	0.004	0.0007
Mohd. Noor Belachan Factory	0.046	0.0195
PULAU AMAN		
Norbed b. Yusof Malay Belachan Factory	0.019	0.0108

* ND : Non-detectable.

60.0-70.7%, 32.7-39.3%, 2.77-4.48% and 38.9-57.6% for cencaluk respectively. Similarly, high levels of Ca, K, Mg, Na and P were detected ranging between 18,200-27,400 ppm, 4,300-12,800 ppm, 1,400-5,100 ppm, 22,800-46,700 ppm and 12,000-14,700 ppm for belacan and 11,800-18,500 ppm, 5,500-12,500 ppm, 1,800-3,200 ppm, 40,600-96,300 ppm and 8,000—11,500 ppm for cencaluk, respectively.

In connection with trace metals the majority of them are below detectable levels (BDL) while Cu, Fe, Hg, Mn and Zn ranged between 5.8—22, 82—540, BDL—0.073, 6.9—35 and 36—75 ppms, respectively.

The PCBs and p, p 'DDE contents in both belacan and cencaluk are given in Table 2. Obviously, their contents are low and range between non-detectable level—0.046 ppm and non-detectable level — 0.0195 ppm for PCBs and p, p 'DDE, respectively.

Discussion

Evidently, it is clear that both belacan and cencaluk are very nutritious ingredients of the Malaysian diet. From the viewpoint of environmental contaminants in it, the present study eliminates the question of health hazards originating from such factors as trace metals, PCBs and persistent pesticides.

Based on the results of the present study, the authors are of the opinion that endeavours should be made by the local government to protect the shrimp paste industry through detailed studies on the availability of natural resources of mysid shrimps and overcoming problems involved in its fishery aspect.

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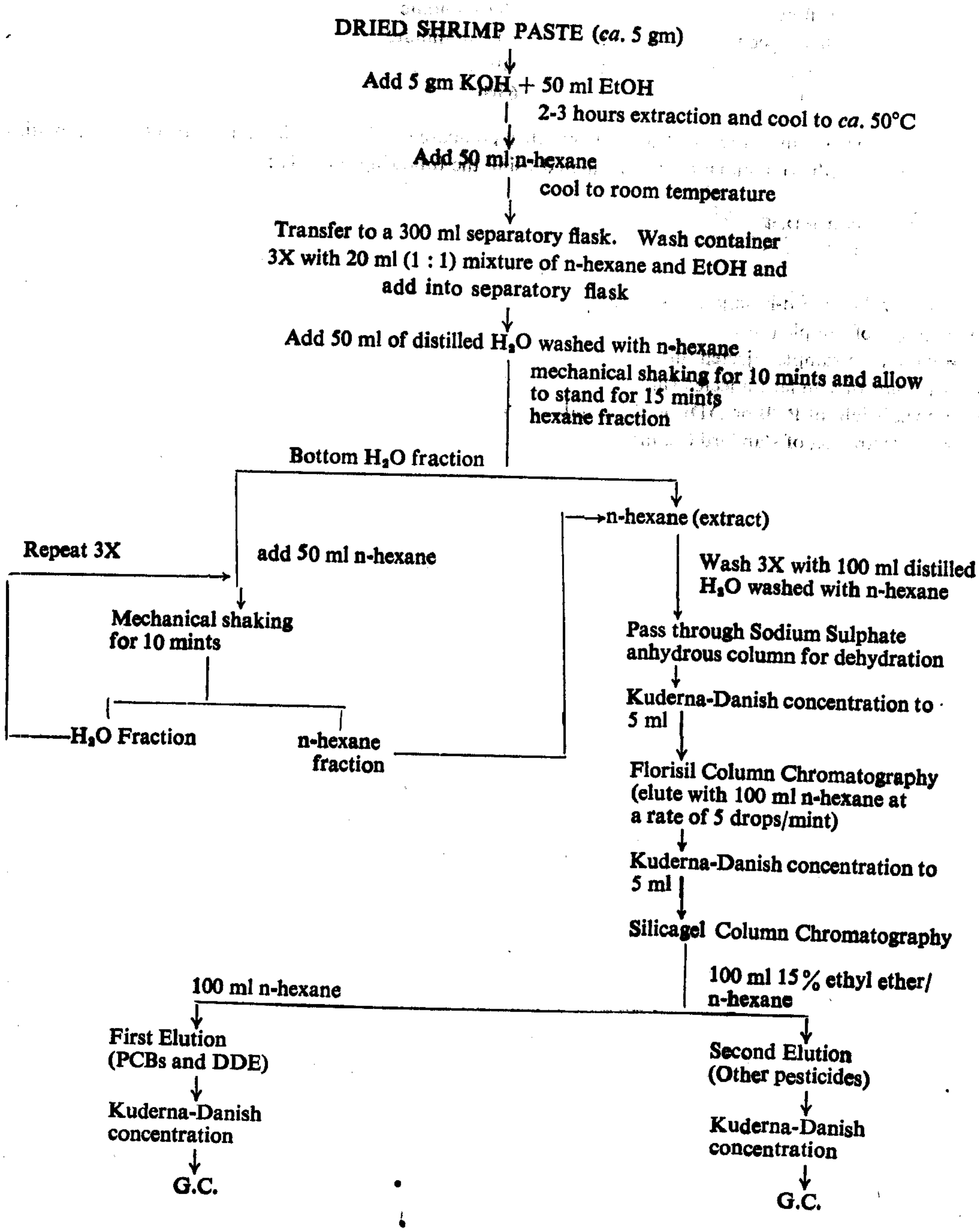
APPENDIX 1

PCBs and persistent pesticides contents in the belacan and cencaluk samples were determined after processing the samples as given below :



After extraction of the PCBs, DDE and other pesticides in fractions 1 and 2 they were subjected to gas chromatographic analysis. A. G.C-4BM Shimadzu gas chromatograph under the following operating conditions was employed.

Column packing	:	OV 17/1.5% Chromosorb W
Detector temp.	:	210°C
Column temp.	:	190°C
N_2 flow	:	30 ml/minute
Chart speed	:	10 mm/minute
Range	:	$10^2 \times 8$
ECD	:	^{63}Ni

The gas chromatogram of the two fractions was then compared with authentic samples of PCBs and pesticides and the amount of both contaminants was calculated using the following formula :

$$\frac{V \times h_{\text{PCB or DDE}} \times V^1}{m \times v \times h} \times C = \text{result in ppm}$$

where

V = total volume of n-hexane extract (ml)
m = weight of sample (gm)
v = volume of sample injected (ul)
V^1 = volume of standard injected (ul)
h^1 = peak height of PCB or DDE in the standard (mm)
C = concentration of standard (ug/ul)

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EVALUATION OF SUPPLEMENTARY FEEDS FOR *PENAEUS INDICUS*

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ABSTRACT

Three sets of yard experiments are conducted to determine the effect of supplementary artificial feeds prepared from cheap and locally available materials on the growth and survival of *Penaeus indicus*. Feeds were prepared using eleven items—fish meal, prawn factory waste, groundnut oil cake, gingely oil cake, blackgram husk, Bengalgram husk, bajra (Kambu), wheat flour, wheat bran, rice bran and tapioca. A combination of fish meal, rice bran and tapioca in two proportions of 1 : 1 : 1 and 2 : 2 : 1 respectively proved to be the best among the feeds experimented with, giving good growth, survival and conversion. Though equally rich in protein content, the feeds prepared with prawn factory waste were not found to be as efficacious as the one with fish meal. Shell powders and other additives did not give any desired effect.

INTRODUCTION

IN recent years there has been an upsurge in the culture of penaeid prawns as a result of the phenomenal rise in their export demand and value. Though much attention has been paid to their various culture aspects, very little information is available at present on the artificial feeds and feeding of penaeid prawns. Intensification of culture practices and large-scale stocking of fish may lead to depletion of natural protein available in the environment and this affects fish growth. (Hepher and Chervinski, 1965). Artificial feeding is the only satisfactory solution to overcome this problem. Herein lies the need to develop cheap and efficacious feeds. With this aspect in mind three experiments were conducted using different combinations of cheap and locally available feedstuffs as supplementary feeds for *Penaeus indicus* to assess their effect on its growth.

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MATERIAL AND METHODS

Live specimens of juvenile *P. indicus* were collected from Pulicat Lake by velon net, and reared in sea water kept in plastic pools and cement tubs of area 0.60 sq.m and 0.16 sq. m respectively. Prior to the experiment the prawns were acclimated to the laboratory conditions for a week.

The following items were used as ingredients in the formulation of feeds :

Fish meal, prawn factory waste, groundnut oil cake, gingely oil cake, blackgram husk, Bengalgram husk, bajra, wheat flour, wheat bran, rice bran and tapioca.

Fish meal was prepared from *Leiognathus* sp. of size range 35-50 mm, available at Pulicat at cheap rates and not preferred much for human consumption. Prawn factory waste consisting of head, gut and body shell was collected from Pulicat, from the centres where prawns were processed for export. Algal powder was prepared from the green algae *Enteromorpha* sp. and *Chaetomorpha* sp. Oyster shell powder was prepared from the shell of *Crassostrea madrasensis*. The vitamins used were pharmaceutical preparations available in the local market. The other feed items were purchased from the local market. Price index of the various feeds is given in Table 1.

TABLE 1. *Cost of different feed items per kilogram (transportation and grinding charges not included)*

Feed item	Cost Rs. P.
Bajra	1.00
Bengalgram husk	1.00
Blackgram husk	1.00
Fish meal	2.50
Gingely oil cake	2.00
Groundnut oil cake	1.30
Rice bran	0.40
Tapioca powder	1.50
Wheat bran	0.70
Wheat flour	1.40

Constituents of all the feeds were dried, ground, powdered and sieved. They were mixed in fixed proportions. Tapioca powder was added after boiling. It served as a binder as well as a source of carbohydrate. In one feed, wheat flour served this purpose. The mixtures of various feeds were made into a dough and pelleted with the help of a hindalium hand-press using a die of 5 mm diameter. The pellets were sundried, stored in air tight containers and kept in a cool place.

The required quantity of feed was weighed in a physical balance and placed in bakelite feed trays of diameter 7 cm. The pellets were broken down to small sizes and the trays were slowly immersed in water to the bottom of the tubs. While placing and removing maximum care was taken to avoid spilling. The prawns were fed daily in the morning at the rate of 10% of body weight. At the end of the day the left over feed in the tray was removed, dried and the weight determined.

The dirt accumulating at the bottom of the containers was siphoned out daily and fresh sea water was added to make up the water level.

During the experimental period temperature ranged from 23.5 to 32.0°C. Dissolved oxygen (D.O) was recorded at weekly intervals using Winkler's method and it ranged from 3 to 14.0 ppm.

Details of the three experiments are given below.

Experiment No. 1

6 plastic pools, each of 400 litre capacity were used. 20 numbers of *P. indicus* of length range 27-59 mm were stocked in each pool containing about 200 litres of sea water. Three feeds were provided in two replications each.

Feed I (Fr-1) — Rice bran (control).

Feed II (F-2) — Prawn factory waste, groundnut oil cake and tapioca (2 : 2 : 1).

Feed III (Ffm-3) — Fish meal, rice bran and tapioca (1 : 1 : 1).

Experiment No. 2

10 cement tubs, each of 80 litre capacity were used. 10 numbers of *P. indicus* of length range 32-58 mm were stocked in each tub, containing about 40 litres of sea water. Five feeds were provided in two replications each.

Feed I (Ffm-4) — Fish meal, rice bran and tapioca (2 : 2:1).

Feed II (F-5) — Prawn factory waste, blackgram husk, groundnut oil cake and tapioca (2 : 2 : 1 : 1).

Feed III (F-6) — Wheat bran, bajra and tapioca (1 : 1 : 1).

Feed IV (F-7) — Wheat flour, Bengalgram husk and gingely oil cake (2 : 2 : 1).

Feed V (Fr-8) — Rice bran (control).

Experiment No. 3

12 cement tubs of above measurements were used. 10 numbers of *P. indicus* of length range 27-68 mm were stocked in each tub containing the same volume of water as mentioned above. The six feeds provided in two replications, each had a common base consisting of fish meal, rice bran and tapioca in the ratio of 2 : 2 : 1. To this common base, different organic substances and vitamins were added. Feed I consisted only of the base material and was used as control ; and Feed V also consisting only of base material was provided with aeration.

Feed I (Ffm-9) control
Feed II (F-10).... Algal powder (10% of feed)
Feed III (F-11).... Oyster shell powder (5% of feed)
Feed IV (F-12).... Vitamins (10.88 mg daily)
Feed V (F-13).... Aeration
Feed VI (F-14).... Prawn shell powder (10% of feed)

Measurements and weights of prawns were taken initially and at monthly intervals. Length of prawns was taken from the tip of the rostrum to the tip of the telson, and weight was taken using a monopan balance, keeping the live specimen in a pre-weighed container with water.

In Experiment No. 3 mortality was very low, but when it did occur the dead prawns were replaced by live specimens to maintain equivalent densities in the containers.

Conversion factor was calculated according to the method mentioned by Halver (1972).

Chemical analysis of four feeds—Ffm-4, F-5, F-6 and F-7 was carried out (Table 2). Moisture content was found by computing the differences between sundried feed and feed kept in an oven at 60°C for 24 hours. Protein analysis was done by Micro-Kjeldhal's method according to the procedure followed by Steyermark (1961). Fat analysis was done according to the method followed by Bligher and Dyer (1959). Ash content analysis was done using

TABLE 2. *Nutritional analysis of four feeds fed to juvenile* P. indicus

	Feed Ffm-4	Feed F-5	Feed F-6	Feed F-7
	Fish meal, rice bran & tapioca	Prawn factory waste, blackgram husk, groundnut oil cake & tapioca	Wheat bran, bajra & tapioca	Wheat flour, Bengalgram husk & gingely oil cake
	(2 : 2 : 1)	(2 : 2 : 1 : 1)	(1 : 1 : 1)	(2 : 2 : 1)
Moisture	12.1	10.3	24.6	13.7
Protein	29.4	40.0	15.9	24.2
Fat	1.4	1.0	1.3	1.8
Ash	22.1	19.8	4.0	6.2
Carbohydrate & Crude fibre	35.0	29.9	54.2	54.1

a muffle furnace and ashing was carried out for a period of 12 hours at 550°C. The difference calculated was reckoned as carbohydrate and crude fibre.

RESULTS

All the feeds tried were avidly consumed by the prawns. The results of the three experiments are summarised the average growth rate depicted in figures 1, 2 and 3.

In experiment No. 1, where the feed Ffm-3 (Fish meal, rice bran and tapioca in the ratio of 1 : 1 : 1) was used, maximum gain in weight. survival and conversion were obtained. This was followed by Feed F-2 (Prawn factory waste, blackgram husk, groundnut oil cake and tapioca in the ratio of 2 : 2 : 1 : 1). In the case of the control feed Fr-1 (rice bran) no growth was observed. (Fig. 1).

As can be seen from Table 5 and figure 2, in Experiment No. 2, feed Ffm-4 (Fish meal, rice bran and tapioca in the ratio of 2 : 2 : 1) proved to be the best in all respects. Feed F-7 was the next in order of acceptability. Feeds F-5 and F-6 were the least satisfactory. In the case of Fr-8, the control feed (rice bran), again no growth was observed.

In Experiment No. 3, the standard feed combination—fish meal, rice bran and tapioca of the first and second experiments, when tried out in the ratio of 2 : 2 : 1, resulted in better growth and biomass conversion (Fig. 3). Further when aeration was provided along with this feed, it had an enhancing effect on growth and conversion. The conversion factor was 2.98 with aeration compared to 3.32 without aeration. Algal powder, oyster shell powder, prawn shell powder and vitamins did not give any added beneficial effect and the conversion factors are 3.77, 3.53, 3.97 and 5.36 respectively.

In all the tubs there was growth of algae,for which the prawns showed preference.

The conversion factor and economies of the promising feed formulation are given in Table 3.

DISCUSSION

P. indicus is reported to be an omnivorous feeder (Rao 1971). In this series of experiments it was found that it accepted all the feeds that were given, but seemed to have a preference for the feed which contained fish meal as is indicated by the better rate of consumption. According to Bhanot and Gopalakrishnan (1973) fish meal is an ideal protein item having

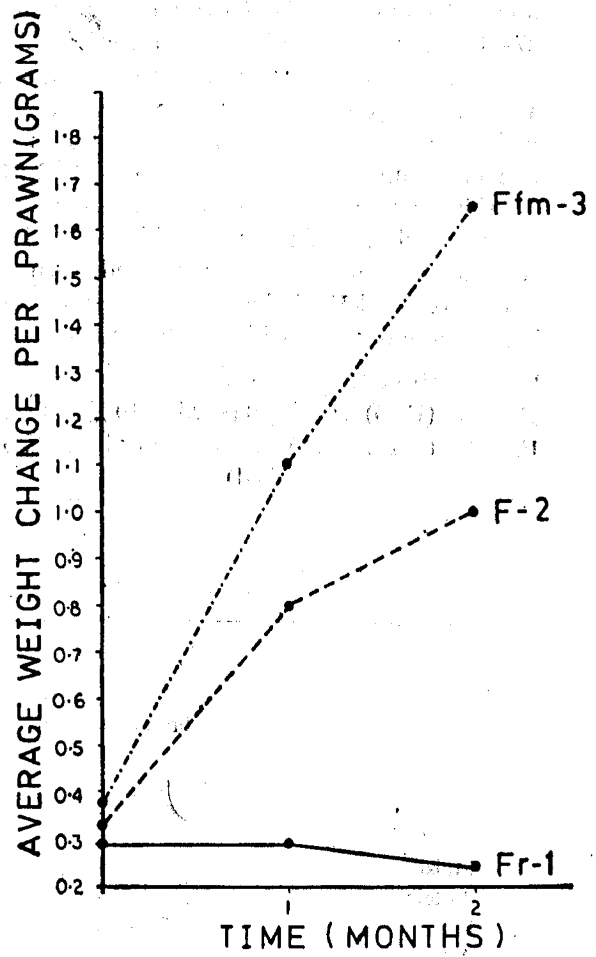

Fig. 1. Result of experiment No. 1 depicting the average growth rate of *P. indicus*.

all the essential aminoacids required in fish feeds. In the experiments conducted here better results were obtained with feeds which contained fish meal. Feeds Ffm-3 and Ffm-4 containing 33.33% and 40% of fish meal respectively gave better results than feeds F-2 and F-5 containing 40% and 33.33% of prawn factory waste respectively. Chemical analysis of feeds F-5 and Ffm-4 for instance revealed that the former contained a higher percentage of protein (40.0%) than the latter (29.4%). From this it appears that feed F-5 may contain protein which is not as digestible as that in fish meal.

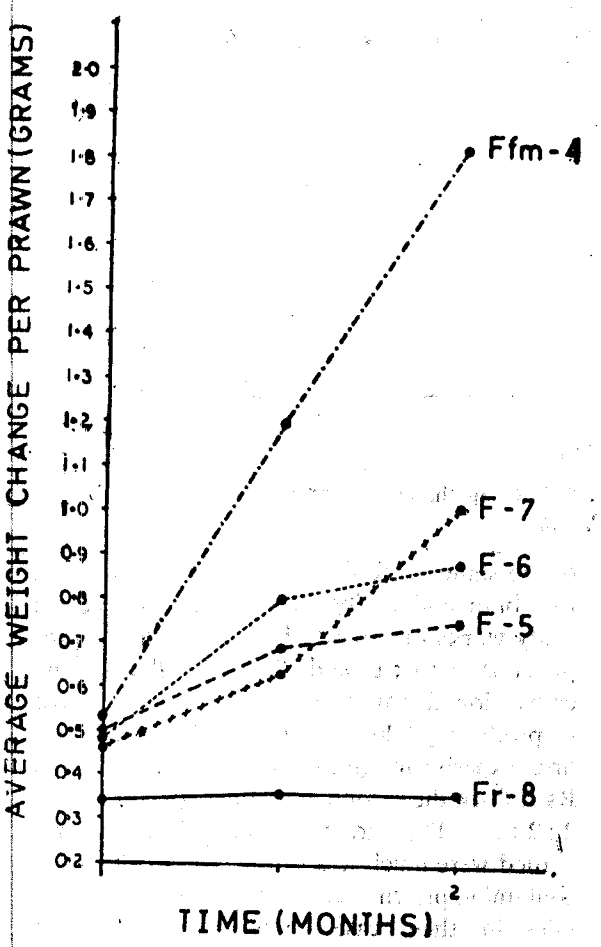

Fig. 2. Result of experiment No. 2 depicting the average growth rate of *P. indicus*.

Prawn factory waste not rating as high as fish meal corroborates the findings of Robinette and Dearing (1978). 'The poor performance of channel catfish (*Ictalurus puncatus*) on the shrimp by-product diets probably indicates that the shrimp by-product meal was either not as digestible or as palatable as fish meal or that the shrimp by-product meal was deficient in some unidentified factor'.

As can be seen from Table 5 and figure 2, in Experiment No. 2, feed Ffm—4 (Fish meal, rice bran and tapioca in the ratio of 2 : 2 : 1) proved to be the best in all respects. Feed F—7 was the next in order of acceptability. Feeds F5 and F6 were the least satisfactory. In the case of Fr—8, the control feed (rice bran), again no growth was observed.

Substances like oyster shell powder, prawn shell powder, algal powder and vitamins, when added along with the standard feed combination of fish meal, rice bran and tapioca in the ratio of 2 : 2 : 1, did not help in enhancing the growth further. It should be mentioned here that the vitamins had not been mixed with base feed during its preparation but were supplied to the prawns daily along with it.

The conversion factors obtained for the standard feed combination of fish meal, rice bran and tapioca were the best in all the experiments. Feed Ffm-3 with the ingredients in the proportion of 1 : 1 : 1 gave a conversion efficiency of 1.69 and feeds Ffm-4 and Ffm-9 with the ingredients in the proportion of 2 : 2 : 1 exhibited a conversion efficiency of 3.21 and 3.32 respectively.

Provision of aeration is the factor that has to be taken into consideration, for it had an enhancing effect on the performance of the standard feed.

The economics of the various feed mixtures are set forth in Table 3. The per kilogram cost

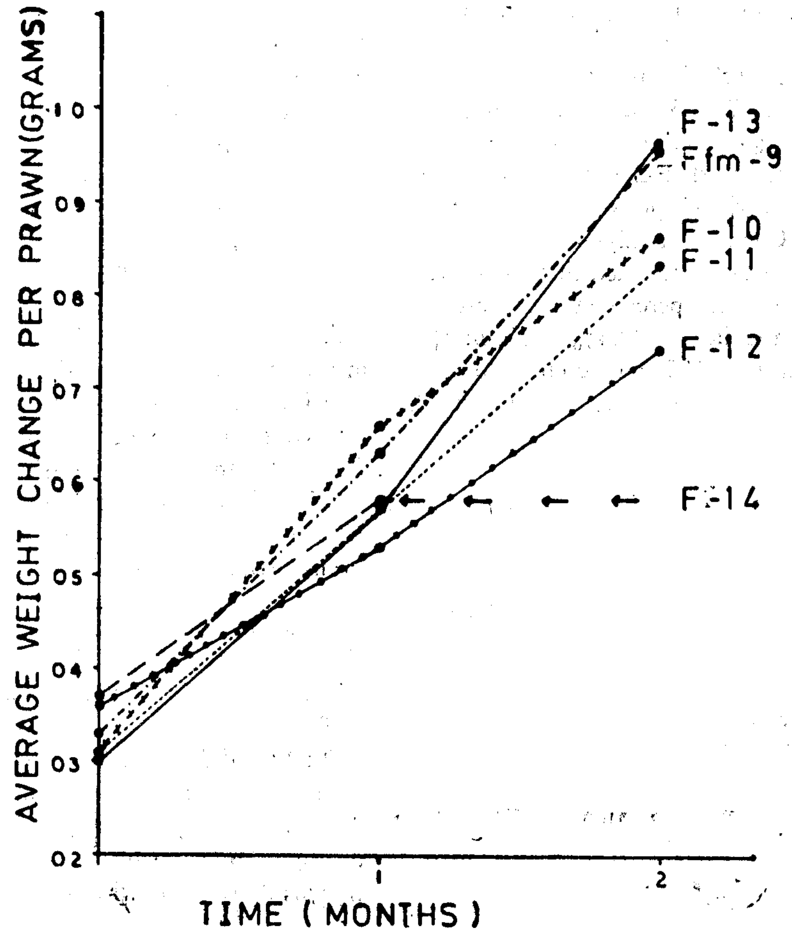

Fig. 3. Result of experiment No. 3 depicting the average growth rate of *P. indicus*.

TABLE 3. *The economics of certain feeds fed to juvenile* P. indicus

Code	Cost of feed per kg Rs. P.	Conversion factor	Cost of feed required to produce one kg of prawn Rs. P.
F-2	0.82	4.40	3.61
Ffm-3	1.46	1.69	2.47
Ffm-4	1.46	3.21	4.69
F-5	0.80	12.94	10.35
F-6	1.04	37.08	38.56
F-7	1.36	4.24	5.77

of the standard feed combination of fish meal, rice bran and tapioca evolved in the present study works out to Rs. 1.46 for both the proportions 1 : 1 : 1 and 2 : 2 : 1. Taking the conversion factor into consideration, the cost of producing 1 kg of prawn is Rs. 2.47 in the first experiment (feed formula 1 : 1 : 1) and Rs. 4.69 in the second experiment (feed formula 2 : 2 : 1). The growth and conversion recorded were much less in the case of the feeds containing prawn factory waste, yet the economics in their case works out to be cheap (Rs. 3.61/kg of prawn) because of the free availability of prawn factory waste.

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AN ARTIFICIAL PRAWN FEED COMPOUNDED WITH FROG FLESH WASTE AS THE MAIN INGREDIENT

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ABSTRACT

Preliminary investigations conducted by the Tamil Nadu Mariculture Research Station at Kovalam, near Madras on prawn feed formulation by using frog flesh waste, collected from processing plants as main ingredient were proved to be nutritious and quite acceptable with high conversion value. Conversion ratio ranged from 3.01 to 4.96 with regard to *Penaeus indicus* and from 5.87 to 8.21 with regard to *Penaeus monodon.*

INTRODUCTION

RECENTLY much attention is being paid for intensive culture of different quick growing varieties of prawns, since they have both high nutritional and export value. Supplementary feed enables increased stocking density, increased growth, increased production per unit area ; Eventhough supplementary feed materials like clams and mussels give very good conversion value for prawns, their culture techniques under widely fluctuating environmental conditions have not been perfected and their supply from natural sources are limited. Because of this constraint it has become highly necessary to formulate cheap and efficient supplementary compounded feeds with readily available local materials.

Griteria for a good compounded prawn feed are that it should readily be acceptable and digestible and also should have high conversion value with a good shelf life. Also they should contain the required quantity of protein, carbohydrates, fats, minerals and vitamins in correct proportions to promote growth which in turn will lead to increased production. It should have the ability to stay in water at least 3 hours without disintegration. Such a high quality compounded prawn feed using frog flesh waste obtained from frog-leg processing plants in and around Madras city as main ingredient was prepared by the Tamil Nadu Mariculture Research Station, Kovalam situated 36 km south of Madras. In this paper, a detailed report is given of the ingredients used in the compounded prawn feed and their nutritional quality, method of preparation of compounded feed and its conversion value.

The authors are grateful to the Director of Fisheries, Government of Tamil Nadu for according permission to present this paper in the Symposium. They are also thankful to Thiru A. Sreenivasan, Joint Director of Fisheries for his valuable guidance and suggestions.

MATERIAL AND METHODS

Using frog flesh waste collected from processing plants, as the main source of protein a compounded feed was prepared. In the compounded feed, urea was added to extract the Myosin group of proteins from the flesh to make the feed elastic, since the Myosin group of proteins possess elastic property between 40°C-60°C. The addition of polyphosphate in the feed mixture acted as an antibiotic and anti-oxidant. Required quantity of common salt added to the ingredient mixture served as a binder to prevent lacking in addition to increase storage property. Sufficient quantity of molasses was added to act as a binding agent and a preservative. To increase the bulk of feed and to facilitate easy movement of the feed inside the digestive track crude fibre was also added in the form of rice bran. Few drops of citric acid were added as a source of Vitamin C. As the frog flesh itself has elastic property and the addition of tapioca powder having binding quality, a separate binding agent was not used in the present case for pelletising the compounded feed. After drying, the strands were broken into 3 to 5 mm pieces which is the ideal size for prawns (Sick *et al.*, 1972).

With fish meal as the main source of protein another compounded feed (B) was prepared.

Quantity of different ingredients used in formulating the prawn feed are given in Table 1.

The pellet feed was thrown uniformly into the cages where prawns were reared. Prawns were fed with pellets at the rate of 30%, 15%, 5% of the total bodyweight for the first, second and third month periods respectively. Furukawa (1973) pointed out that prawns from 1 gm stage onwards stop day time feeding. In the present experiment also feeding was done once a day just before sun set.

Most important compounding consideration is water stability of the pelletised feed as prawns have slow feed response. Though any sort of binding material was not added in making pellets, water stability of the compounded feed was found to be 18 hours, which was due to the elastic property of frog flesh with urea at 40°C-60°C and also due to the binding quality of tapioca powder and molasses.

Laboratory analysis of the prepared pellets revealed the proximate composition as detailed in Table 2.

To test the efficiency of the pellet feed made out of frog flesh waste as main ingredient over other types of feeds such as flesh of clam

TABLE 1. *Percentage composition of different ingredients used in formulating the two types of prawn feed*

PELLET A		PELLET B	
Frog flesh waste	58	Fish meal	35
Prawn head meal	6	Tapioca powder	25
Seaweed powder	6	Algal powder	4
Groundnut oil cake	4	Shell grit	1
Rice bran	20	Rice bran	35
Tapioca powder	1	few drops of citric acid	
Molasses	3		
Urea and polyphosphate	0.5		
Salt	1.5		
few drops of citric acid			

Meretrix casta and pellets made out of fish meal, in the main ingredient, five sets of experiments were conducted in Kovalam Backwater in 1978-'79. The experiments were carried out in sixteen 10×5×1 metre velon screen cages suspended in such a way that 2/3 portion of the cage was kept immersed. Twelve cages were stocked with *P. indicus* at the rate of 500/cage in three sets of experiments, i.e., 4 cages for each of the four types of feed and 4 cages were stocked with *P. monodon* at the rate of 60/cage in two sets of experiments, i.e., 2 cages for each of the two types of feed (frog-flesh pellet and flesh of clam). Conversion ratio was worked out in each case separately by dividing the total amount of feed given by the net increase in total weight of prawn.

RESULTS

Growth and conversion data of cage cultured *P. indicus* and *P. monodon* with different types of supplementary feeds are presented in Table 3 and 4. In both the species, satisfactory growth rates have been obtained on formulated feed using frog flesh waste as main ingredient. Relative conversion rates of cage cultured *P. indicus* and *P. monodon* with regard to feed to prawn ranged from 3.01 to 4.96 and 5.87 to 8.21 respectively. Higher conversion was achieved in the case of *P. indicus* over that of *P. monodon*.

To assess the efficiency of the pellet feed using frog flesh with other types of feeds statistical treatment of data was carried out by applying 'T' test. When frog flesh waste pellets was given as supplementary feed to *P. indicus* an average growth increment of 7.83 gm in 100 days was obtained; in clam flesh fed counterparts the average growth increment was 6.21 gm for the same period of rearing (T = 3.17, P 0.5). Similarly the growth increments of prawns fed with frog flesh waste—pellet was significantly higher than that of fish meal—pellet fed prawns (T = 7.33, P 0.5).

In the case of *P. monodon* cultured with frog flesh waste—pellet as supplementary feed an average growth increment of 18.348 g was obtained which was more than the average growth increment (15.8 gm) of clam flesh fed counterpart. Growth difference of 2.548 gm was not statistically significant (T = 2.73; P 0.5) in the case of *P. monodon*. However, there was considerable difference in total weight of prawn harvested due to the higher survival rate when fed with frog flesh waste—pellet.

In conclusion it is necessary to point out the

TABLE 2. *Proximate composition (%) of supplementary feeds used in prawn culture experiments*

Composition	Types of feed		
	Pellet-A	Pellet-B	Flesh of *Meretrix casta*
Moisture	7.49	12.48	75.26
Fat	8.78	3.41	2.10
Crude protein	35.75	18.39	10.33
Carbohydrate	9.29	50.67	3.75
Ash	38.68	12.53	2.06

TABLE 3. *Growth and survival rates of* Penaeus indicus *cultured in* 10 *Sq. m nylon cages for* 100 *days* (*In each cage* 500 *prawns with an average length of* 32.2 +1.45 *mm and average weight of* 0.13 +0.044 *were stocked*)

Experiment No.	Cage No.	Type of feed	Average increase in length at the time of harvest (mm)	Avergae increase in weight at the time of harvest (gm)	Survival rate (%)	Total weight of prawn harvested (kg)	Conversion
I	1	Frog flesh	72.9	7.28	99	3.7	3.01
	2	Pellets	72.1	7.58	99	3.8	4.09
	3		81.8	8.91	70	3.3	4.96
	4		73.9	7.54	89	3.4	4.62
II	1	Flesh	62.5	5.11	98	2.5	7.18
	2	of clam	65.2	5.93	100	3.2	5.90
	3	*Meretrix*	67.4	6.51	98	3.3	6.49
	4	*casta*	70.4	6.95	95	3.5	5.82
III	1	Fish-meal	62.7	4.36	70	2.1	8.53
	2	pellets	54.3	4.64	83	2.0	8.07
	3		53.8	4.81	89	2.2	7.70
	4		57.2	4.65	90	2.2	7.37

TABLE 4. *Growth and survival rates of* Penaeus monodon *culture in* 10 *Sq. m nylon cages for* 95 *days* (*In each cage* 60 *prawns were stocked. The average length and weight in experiment I was* 45.3 *mm and* 1.02 *g* ; *in experiment II*; *it was* 69.1 *m and* 2.85g)

Experiment No.	Cage No.	Type of feed	Average increase in length at the time of harvest (mm)	Average increase in weight at the time of harvest (gm)	Survival rate (%)	Total weight of prawn harvested (kg)	Conversion ratio
I	1	Frog flesh	77.2	18.30	95	1.100	5.87
	2	pellet feed	79.2	18.47	98	1.2	8.21
II	1	Flesh	53.5	14.9	40	0.4	11.70
	2	of clam	57.5	16.7	68	0.7	9.45

fact that while Forster (1975) suggests a good conversion ratio of about 2 : 1 as being a reasonable target, in the present observation conversion ratio appears to be low. But improved techniques and necessary alterations in the ingredients used for feed preparation, in the near future would definitely lead to better conversion.

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BIOCHEMICAL STUDIES ON 'SOFT' PRAWNS : 1. PROTEIN NITROGEN AND NON-PROTEIN NITROGEN CONTENTS IN *PENAEUS INDICUS*

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ABSTRACT

The tail portion of both the healthy and 'soft' prawns (*Penaeus indicus*) collected from experimental ponds, was analysed for Protein nitrogen (PN) and Non-protein nitrogen (NPN) to find out to what extent the two fractions of the total nitrogen (TN) vary under these two conditions. The analysis reveals that the NPN fraction is considerably higher in the case of 'soft' prawns as compared to that of the healthy prawns. It is assumed that the increase of NPN content in 'soft' prawns may be due to endogenous protein metabolism caused by changes in the ecosystem during the period of extreme ecological conditions.

INTRODUCTION

PRAWNS are known to become 'soft' in brackishwater culture ponds during the period of adverse ecological conditions like low salinity, high temperature, over crowding, etc. This is one of the major problems in intensive prawn culture operations, as heavy mortality is noticed following such 'soft' condition. The causative factors that lead to the 'soft' condition have not been thoroughly studied. The present investigation was aimed at finding out the possible causative factors for such a condition through biochemical and physiological studies.

It is well known that proteins are ubiquitous components of all living tissues and serve indispensable functions in cellular architecture and are intimately concerned with virtually all physiological events (Mahler and Cordes, 1968). Therefore, any change in the physiology of the organism as a result of adverse ecological conditions is bound to affect the protein content of the tissues qualitatively as well as quantitatively.

Hence, the first part of the investigation deals with the quantity of protein nitrogen (PN) and non-protein nitrogen (NPN) present in the tissues of the 'soft' prawn *Penaeus indicus* and reports on the possibility of protein starvation as the causative factor for softness in prawns based on experiments carried out in the laboratory.

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MATERIAL AND METHODS

The prawn *P. indicus* were collected from experimental ponds at Narakkal during the period of southwest monsoon when the salinity of the pond water was low (range : 1.61 to 2.25‰). The tail portion was separated after measuring the total length and noting the sex of the prawn. The exoskeleton was removed and the flesh was weighed after removing the adhering water with a blotting paper. After drying at a temperature of 85°C, the flesh was weighed to find out the percentage water content in the flesh. The dried material was ground into a fine homogenous powder and was packed in injection vials and preserved. Aliquots were taken from the sample for the estimation of TN and NPN.

TN was estimated by Micro-Kjeldahl method (Vogel, 1971) with the distillate collected in a 2% boric acid solution. NPN was estimated after separating the protein in 10% Trichloroacetic acid (Jacobs, 1951). All samples were analysed in duplicate. PN was computed by subtracting NPN from TN. Protein was calculated by multiplying PN with 6.25 (Love, 1957).

Also, feeding experiments were carried out in the laboratory on ' soft ' prawns (*P. indicus*) collected from experimental ponds to find out to what extent the quality of the food consumed affects the ' condition ' of the prawn. The prawns were divided into two groups. One group was fed with a carbohydrate rich food (boiled rice) whereas the other group was fed with a protein rich food (prawn meat). The experiment was repeated three times with different sets of individuals and was carried out in 3′ dia. plastic pool with a water depth of about 50 cm. During the period of experiment the ambient salinity ranged from 2.45 to 2.48 %° and the ambient temperature from 25 to 28°C. The food was supplied *ad libitum* in both cases. The changes in the condition of the prawn was examined by feeling the prawns with the fingers. The experiments was run for periods ranging from 5 to 20 days.

RESULTS

The amount of TN present in the tail was more or less similar in both ' soft ' and healthy prawns. It ranged from 13.39 to 15.17% (mean ± SD = 14.61 ± 0.52%) and from 13.53 to 15.57% (mean ± SD = 14.82 ± 0.62%) of the dry weight in ' soft ' and healthy prawns respectively. On the other hand, both the PN and NPN contents showed considerable difference between ' soft ' and healthy prawns. The amount of PN ranged from 9.87 to 11.99% (mean ± SD = 10.88 ± 0.76%) in the former, whereas in the latter it ranged from 11.12 to 12.33% (mean ± SD = 12.1 ± 0.46%) (Fig. 1 a).

The NPN content was in the range of 3.18 to 4.18% (mean ± SD = 3.73 ± 0.50%) in ' soft ' prawns as against 2.41 to 3.10% (mean ± SD = 2.72 ± 0.23%) in healthy prawns. The data were analysed by using student's *t*—test and it was found that the amount of NPN present was significantly higher in ' soft ' prawns ($P < 0.001$). NPN when expressed as a percentage of TN ranged from 20.96 to 30.72% (mean ± SD = 25.57 ± 3.61%) in ' soft ' prawns and from 17.38 to 20.37% (mean ± SD = 18.3 ± 1.00%) in healthy prawns (Fig. 1 b). Both PN and NPN were found to be independent of length. Consequent to a decreased PN value in ' soft' prawns the protein content was found to be less ranging from 61.13 to 74.94% (mean ± SD = 67.92 ± 4.84%) whereas in the healthy prawns it ranged from 69.5 to 78.94% (mean ± SD = 75.65 ± 2.85%) (Fig. 2 a).

Apart from the above-mentioned differences in the quantity of PN and NPN present in ' soft ' and healthy prawns in terms of percentage of the dry matter, there was considerable difference in the quantity of dry matter itself between ' soft ' and healthy flesh when it is related to the wet weight of the flesh. The dry matter content ranged from 14.53 to 20.74% (mean ± SC = 18 ± 2.30%) in the case of ' soft ' prawns whereas in the case of healthy prawns it ranged from 19.61 to 26.91% (mean ± SD = 23.12 ± 2.61%) (Fig. 2 b).

The prawns (*P. indicus*) collected from experimental ponds were found to recover even at a low salinity of 2.45 to 2.48‰ when fed with a protein rich food (prawn meat). But, when fed with a carbohydrate rich food (boiled rice) the control prawns did not recover from their 'soft' condition. The time taken for recovery ranged from 5 to 20 days. In two cases the prawns moulted two times before recovery. The inter-moult period was 10 days in the case of a prawn measuring a total length of 102 mm (♀) and 14 days in the case of a prawn with a total length of 115 mm (♂) (Table 1).

from Fig. 1 a, b that the tissues of 'soft' prawns contain more percentage of NPN that the healthy prawns. This difference in the NPN fraction of TN between the tissues of 'soft' prawns and healthy prawns could be due to the mobilization of tissue protein in 'soft' prawns.

It is interesting to note that in the tissues of *P. indicus* the quantity of TN remained more or less at the same level in both the 'soft' and healthy prawns (Fig. 1 a). In other words, the quantity of PN and hence tissue protein was reduced in 'soft' prawns indicating that the

TABLE 1. *Time taken to recover from the 'soft' condition by the prawns* Penaeus indicus *kept in low saline water (2.45 to 2.48‰) and fed with a protein rich food*

Length (mm)	Sex	Time taken for recovery in days	No of times moulted	Inter Mult Period
92	♀	5	—	—
95	♀	5	—	—
96	♀	10	1	—
102	♀	17	2	10 days
115	♂	20	2	14 days
129	♀	8	1	—

DISCUSSION

The quantity of NPN present in the tissues of fishes has been studied fairly well (Shewan, 1951; Gerking, 1955; Niimi, 1972). On the other hand, little information is available on the amount of NPN present in the tissues of crustaceans.

A knowledge of the quantity of PN and NPN present in an animal tissue is important from the point of the physiological condition of the animal and also from the point of the relative value of its protein content. It can be seen body protein has been catabolized (endogenous protein metabolism) for cellular activities. This could have resulted only under the following circumstances :

(*a*) inadequate availability of protein food in the ecosystem or

(*b*) due to some set-back in protein synthesis. Both the above-mentioned probabilities, which might have resulted due to environmental changes could have affected the anabolic activities of the prawns leading to the 'soft' condition. That the anabolic acti-

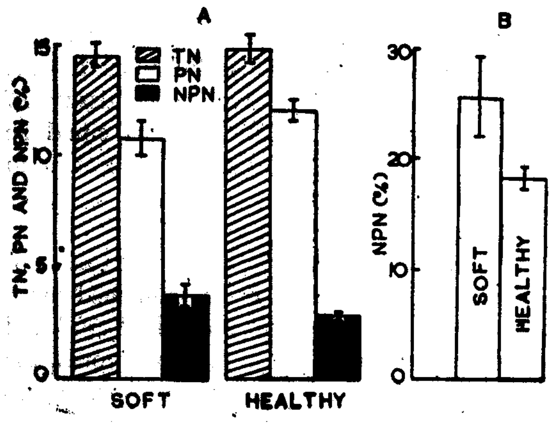

Fig. 1 a. Amount of TN, PN and NPN (expressed as a percentage of dry matter) present in the flesh of 'soft' and healthy prawns (*P. indicus*). The vertical line denotes the standard deviation from the mean values and b. Amount of NPN (expressed as a percentage of TN) present in the flesh of 'soft' and healthy prawns (*P. indicus*).

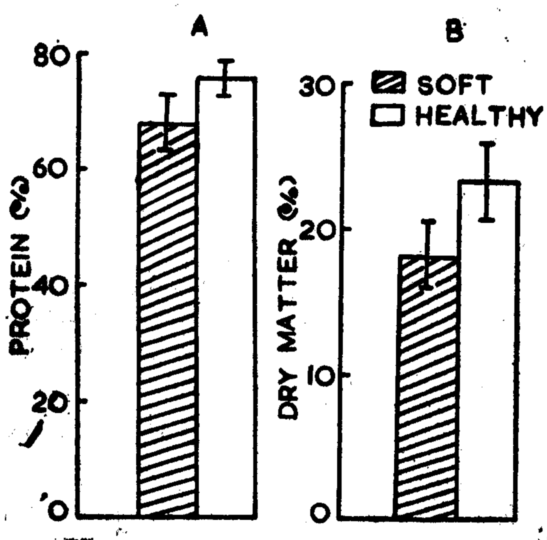

Fig. 2 a. Amount of protein (expressed as a percentage of dry matter) and b. amount of dry matter (expressed as a percentage of wet weight) in the flesh of 'soft' and healthy prawns (*P. indicus*).

vity has been affected in the 'soft' prawn is evident from the percentage of dry matter present in the tissues (Fig. 2 b). Apart from the fact that the dry matter is less in the case of 'soft' prawns when compared to healthy prawns, the protein content in terms of percentage of the dry matter is also considerably less in the former than in the latter (Fig. 2 a). It has been reported by Maynard and Loosli (1969) that during a period of inadequate protein nutrition protoplasm may be broken down to meet certain nitrogenous needs of the body. It is believed that such a thing could have happened in prawns also. This important biochemical fact coupled with a reduction in the quantity of dry matter as a result of physiological set-back following ecological changes in the culture ponds could have rendered the prawns 'soft'.

Experiments carried out in the laboratory has revealed that 'soft' prawns collected from ponds recover from the 'soft' condition when fed with protein rich food (Table 1). On the other hand, the control group fed with a carbohydrate rich food did not recover at all. The time taken for recovery ranged from 5 to 20 days. These findings support the assumption that non-availability of protein food in the ecosystem could have been the causative factor for 'softness' in prawns. However, in the experiment only prawn meat was supplied as protein source and as such it could not be ascertained whether it is simply due to the inadequate quantity of protein food or due to any qualitative or quantitative variation in the amino acid make-up of the food consumed. Further experiments on amino acid levels might throw more light on this.

Though it has been reported by Bell *et al.* (1970) that both synthesis and breakdown are affected by many factors particularly by hormones secreted into the blood by the endocrine glands, the present problem of breakdown of protein does not seem to be related to any endocrine function as the 'soft' prawns recover to healthy condition when fed with protein rich food.

In the light of the above findings the possible causative factor for 'softness' in prawns is schematically summarized as follows:

Adverse ecological condition

↓

Protein starvation

↓

Reduction in tissue protein content

↓

'Soft' condition of the flesh

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OBSERVATIONS ON CERTAIN PARASITES AND DISEASES OF FRESHWATER PRAWN *MACROBRACHIUM EQUIDENS* DANA

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ABSTRACT

Macrobrachium equidens Dana, one of the potentially cultivable species of freshwater prawns, collected for a period of one year from June 1978 to May 1979 from Nethravathy River of Dakshina Kannada was examined for parasites and diseases. The prawns were found to be infected by bacteria, protozoan and isopod parasites. The bacteria produce a disease called shell disease on prawns. The micro-biological tests indicated that the causative organisms were chitinoclastic bacteria such as *Pseudomonas* spp., *Bacillus* spp., *Aeromonas* spp. and *Serratia* spp. Large number of microsporidian cysts attached to the prawn body was noted. The cysts were more in the rostral cavity, antennal scale and uropods and less on the inner wall of the carapace and appendages. A bopyrid isopod parasite attacking the branchial chamber was also encountered. The incidence and intensity of infection and the pathology owing to these infections were described. An instance of the occurrence of tumour on the carapace was recorded.

INTRODUCTION

AQUACULTURE both in freshwater and saltwater is rapidly developing over the world. In the developing countries shrimps are being raised as food. In many countries shrimp farming is a very important economic activity. The parasites and diseases of the shrimp constitute one of the most important problems confronting modern aquaculturist. A clear understanding of the pathogens and methods of treating and preventing the diseases will lead to more efficient and effective husbandry and ultimately better management of the valuable resources.

Considerable information is available on the parasites and diseases of penaeid prawns of commercial importance (Hutton *et al.*, 1959 ; Kruse, 1959 ; Rosen, 1970 ; Sprague, 1970 ; Overstreet, 1973 ; Couch, 1978 ; Johnson, 1978). But literature pertaining to diseases of freshwater prawns of the genus *Macrobrachium* are much limited. Among the freshwater prawns of the genus *Macrobrachium*, the black spot disease or shell disease or brown spot disease has so far been reported from *M. rosenbergii* and *M. Vollenhovenii*. Miller (1971) has described black spot disease on *Macrobrachium vollenhovenii* and reported chitinoclastic bacteria may be the causative organisms for the disease. Dugan *et al.*, (1975) found black spot to be the most prevalent disease of adult *Macrobrachium*. Delves-Broughton and Poupard (1976) described shell lesions and stated that among the three species of bacteria isolated from the shell lesions *Benekea* predominated. Johnson (1978) gave an account on the diseases of the craw fish and freshwater shrimp. The present paper describes the occurrence of parasites and diseases of *Macrobrachium equidens* Dana.

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MATERIAL AND METHODS

Several specimens of *Macrobrachium equidens* were obtained from Nethravathy, Gurupur Estuary of Dakshina Kannada for a period of one year from June 1978 to May 1979 and examined to understand the nature of infestation. Data regarding the date and place of collection of prawns and the total length, carapace length, weight and sex of individual specimen have been collected. Each prawn was carefully examined on the body surface, rostrum, antennal scale, appendages, uropods and telson for the evidence of black spot disease and protozoan cysts. The branchial chamber was examined for the presence of isopod parasites. The abnormal conditions that were visible on the body were also examined.

A total of 287 prawns varying in size from 39 to 110 mm were examined. The sex ratio for male to female was 1.5 : 1. Data regarding the number of black dots or patches, protozoan cysts and bopyrid parasites per host prawn were carefully recorded. The incidence and intensity of infestation in relation to periods, length groups and sex of host were also noted. The terms 'incidence of infestation' was used to mean the ratio of number of infested specimens to the total number examined and the 'intensity of infestation' was the total number of spots or cysts per host. In some instances the ratio was expressed as percentage. Conspicuous swellings on the body surface or enlargements of tissues, if any were also examined. The inner wall of the branchial chamber and the uropods were examined for the presence of blisters.

For microbiological studies, the affected tissues were transferred aseptically to sterilized chitin strip mineral salts liquid medium that contained chitin 1.0; K_2HPO_4 1.0; $7H_2O$ 0.5; NaCl 0.5; $CaCl_2$, $2H_2O$ 0.1; $FePO_4$; $2H_2O$ 0.001; NH_4Cl, 1.0 and distilled water. After complete disintegration of chitin strip, the tissues were transferred to fresh sterilized medium and allowed disintegration of chitin strip to complete. After chitin digestion has occurred, a loop was streaked on to chitin agar medium plates. The agar medium contained 18 grams of agar, in addition to the components given above. Chitin hydrolysing colonies were isolated. Gram staining, spore staining and biochemical tests such as Glatin liquification, caesin and fermentation of various sugars were made to identify the chitinoclastic organisms. The protozoan cysts attached to the body were counted. The cysts were removed from the prawns with the help of fine needles and preserved in formalin for further observations on the same. The bopyrid parasites collected from the branchial chamber of prawns were first washed in salt solution and then in tap water. Preservation was made in 5% formalin for further observation.

RESULTS

Bacteria

Microbiological investigations revealed that the causative organisms for black spot disease were the chitinoclastic bacteria. Based on Bergey's manual of determinative bacteriology (Buchanan and Gibbons, 1974), the isolated organisms were identified. The organisms isolated were *Pseudomonas* spp., *Bacillus* spp., *Aeromones* spp. and *Serratia* spp. in the order of abundance. The main sites of occurrence of this disease were on the carapace, abdomen, appendages, antennal scales, uropods and telson. The nature of infestation of black spot disease has been given in Table 1. From the Table, it is evident that out of 287 prawns examined 57 (19.9%) were infected by bacteria. The percentage infestation during different months presented in Fig. 1 clearly indicates monthly fluctuations and relatively higher values (25% each) during September, December and March and (26.3%) during August were

TABLE I. *Incidence of infestations on* Macrobrachium equidens *by bacteria and protozoa*

				BACTERIA			PROTOZOA			BACTERIA (%)			PROTOZOA (%)		
Month & Year	Male	Female	Total	Male	Female	Total	Male	Female	Total	Male	Female	Total	Male	Female	Total
June 1978	13	7	20	3	1	4	13	7	20	23.8	14.3	20.0	100.0	100.0	100.0
July	19	11	30	1	2	3	11	7	18	5.2	18.2	10.0	57.9	63.6	60.0
Aug.	25	13	38	8	2	10	18	11	29	32.0	15.4	26.3	72.0	84.6	76.3
Sep.	11	9	20	2	3	5	8	5	13	18.2	33.3	25.0	72.7	55.6	65.0
Oct.	10	9	19	1	3	4	8	8	16	10.0	33.3	21.1	80.0	88.9	84.2
Nov.	8	12	20	2	2	4	4	3	7	25.0	16.7	20.0	50.0	25.0	35.0
Dec.	18	22	40	7	3	10	13	11	24	38.9	13.6	25.0	72.2	50.0	60.0
Jan. 1979	14	6	20	2	1	3	6	1	7	14.3	16.7	15.0	42.9	16.7	35.0
Feb.	14	6	20	2	1	3	5	4	9	14.3	16.7	15.0	35.7	66.7	45.0
March	12	8	20	3	2	5	3	3	6	25.0	25.0	25.0	25.0	37.5	30.0
Apr.	14	6	20	1	1	2	4	2	6	7.1	16.7	10.0	28.6	33.3	30.0
May	12	8	20	3	1	4	8	1	9	25.0	12.5	20.0	16.7	12.5	45.0
Total	170	117	287	35	22	57	101	63	164	20.5	18.8	19.9	59.4	53.8	57.1

noticed. The incidence was highest (26.3%) during August and least (10% each) during July and April. Also it has been noted that the mean seasonal percentage infestation was maximum during monsoon and slightly less during post monsoon and least during summer months (Fig. 2).

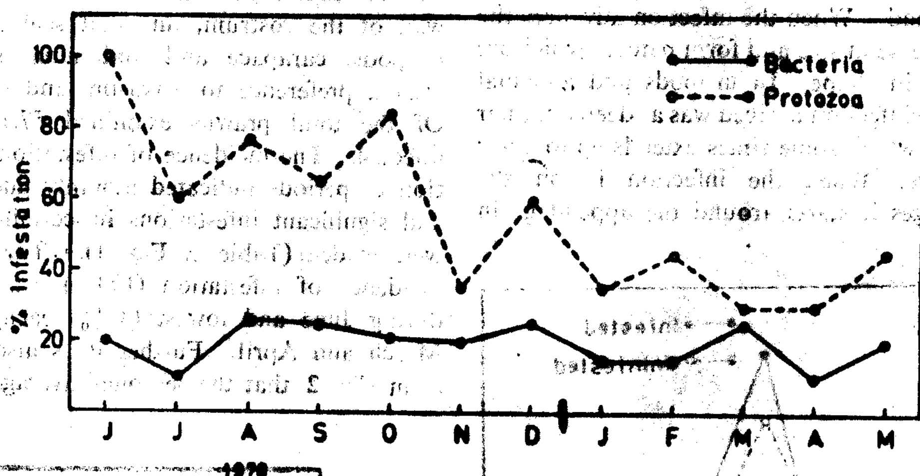

Fig. 1. Incidence of infestation of bacteria and protozoa on *Macrobrachium equidens* in different months.

The average incidence of infestation according to sex indicated that the males were more susceptible to infestation (20.6%) than females (18.8%). The monthwise percentage infestation in relation to sex gave a picture of maximum (38.9) infestation in males during December and least (7.1) during April. While in females the maximum (33.3 each) was recorded during September, October and least (12.5) during May.

The infestation according to length groups has been given in Fig. 3. From the figure it is evident that the infection was maximum (60.31%) in the medium length group (52-71 mm) and thereafter the infestation was observed to be inversely proportional to increase in length groups. Further the infestation was completely absent in prawns of lengths less than 52 mm.

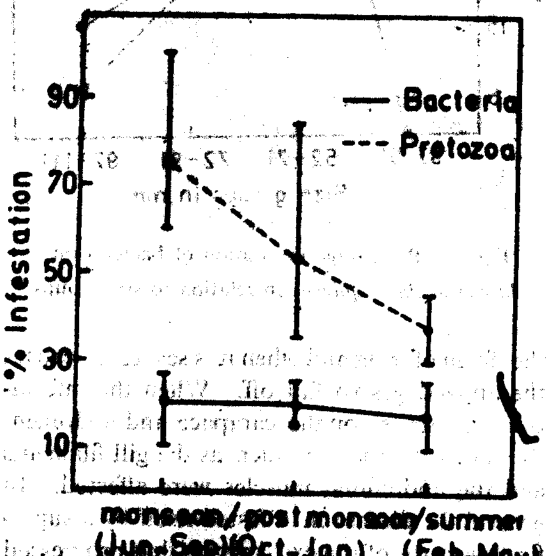

Fig. 2. Percentage infestation of bacteria and protozoa on *Macrobrachium equidens* in different seasons.

In gross observation the signs of the disease was clearly visible on the exoskeleton (Plate I A). The infection begins as black dots and are clearly seen against the light yellow coloured background. When the infection advances the dots increase in size and form patches which are irregular in shape. In uropods and antennal scales the infection noticed was as deep irregular groves, which some times extends up to a few millimetre. When the infection is on the appendages it starts around the appendage in

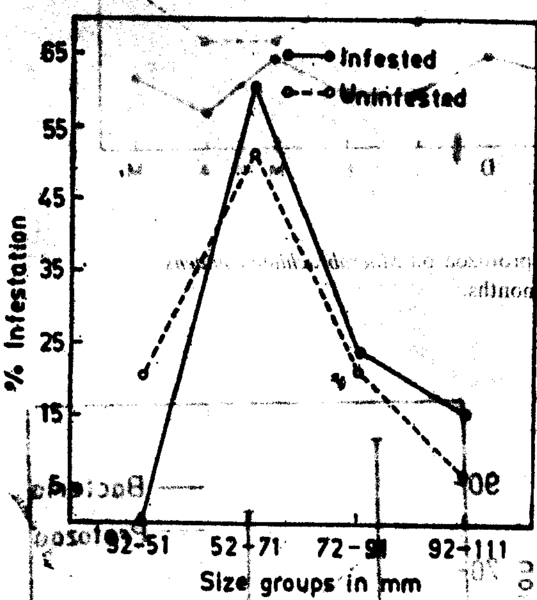

Fig. 3. Percentage infestation of bacteria on *Macrobrachium equidens* in relation to size groups.

the form of ring and when it is severe, it causes the appendages to fall off. When the infestation was severe on the carapace and abdomen, the underlying tissues such as the gill filaments and the abdominal muscles were affected. In general the disease manifested itself by a superficial necrosis of the exoskeleton that progressed from minute spots into widely necrotic areas. Instances were also noticed that the rostrum and the telson were completely damaged due to infection.

Protozoa

Large number of protozoan cysts were found attached to the body (Plate I B). The common sites of occurrence of these cysts were the inner wall of the rostrum, antennal scales, telson, uropods, carapace and abdominal segments with a preference to rostrum and uropods. Of the total prawns examined 57.1% were infected. The incidence of infestation in relation to periods indicated monthly fluctuations and significant infestations in certain months were evident (Table 1, Fig. 1). The highest incidence of infestation (100%) was noticed during June and lowest (30% each) during March and April. Further it is also evident from Fig. 2 that the seasonal average percen-

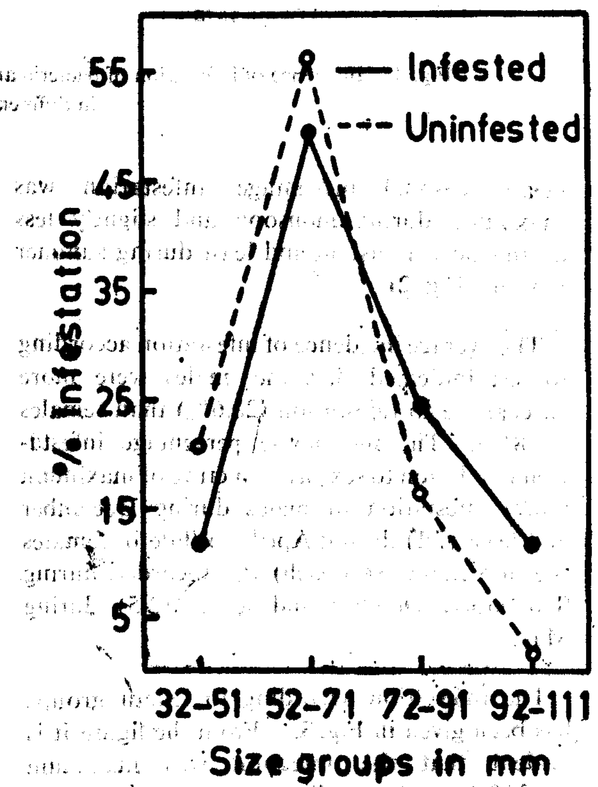

Fig. 4. Percentage infestation of protozoa on *Macrobrachium equidens* in relation to size groups.

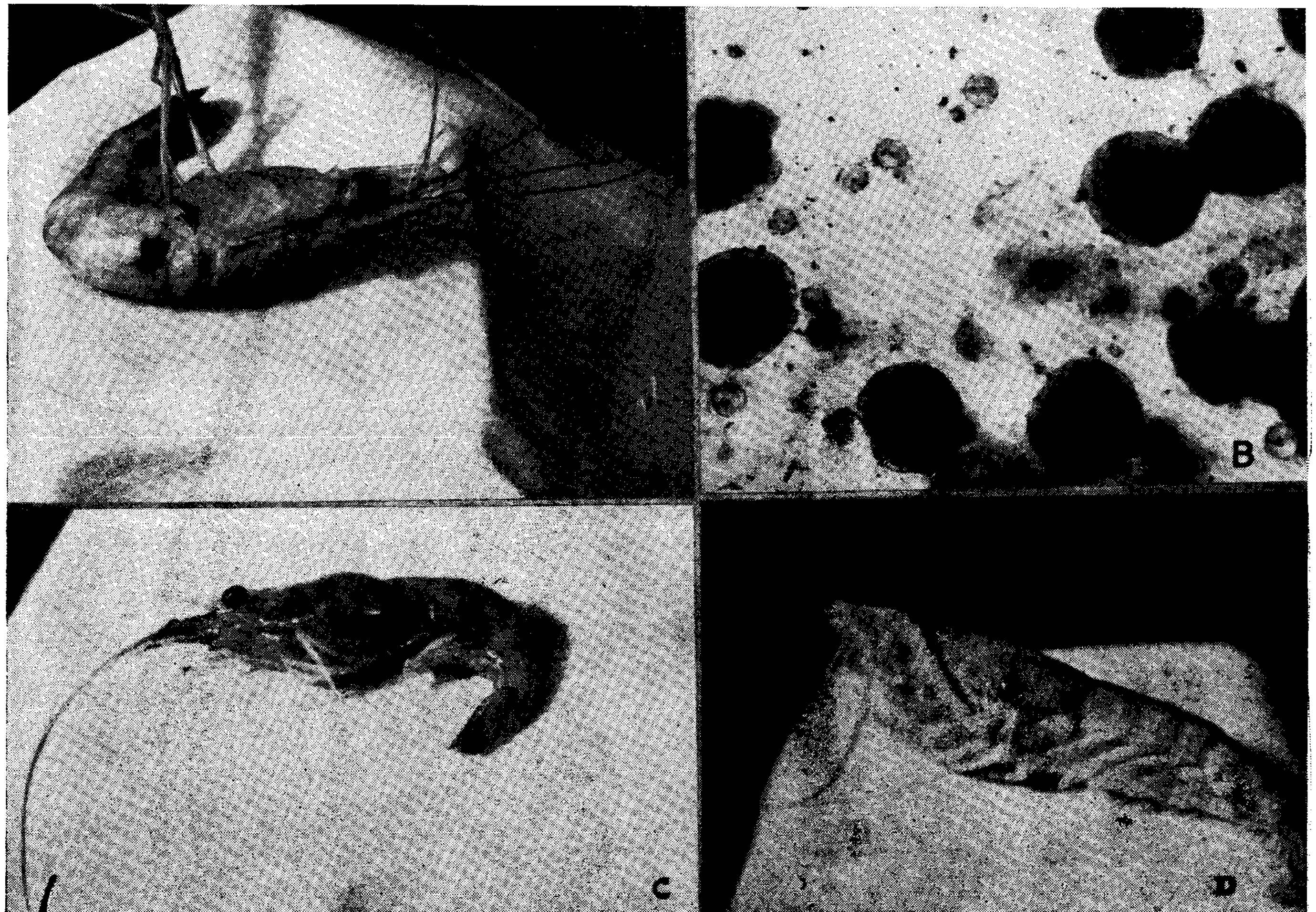

PLATE I. *Macrobrachium equidens* : A. The black spot disease on the exoskeleton ; B. The protozoan cysts in the uropod ; C. The attachment of *Probopyrus* on the branchial chamber ; and D. The attachment of a tumour on the lateral sides of the carapace.

tage infestation was maximum (75.3%) during monsoon less during post monsoon (53.0) and least during summer (37.5).

The incidence of infestation according to sex indicated that the males were more susceptible (59.4%) than females (53.8%). The monthwise percentage infection in relation to sex showed that in males and females the maximum (100% each) was during June and least (16.7% and 12.5% respectively) during May (Table 1).

The percentage infestation according to length groups has been presented in Fig. 4. From the figure it is evident that the infestation was more (49.1%) in the medium length group (52-71 mm) and less (24.2 and 13.3%) in the higher length groups (72-91 and 92-111 mm). The infestation was also less (13.3%) in the smaller length group (32·51 mm).

The average intensity of infestation has been given in Fig. 5. It is obvious from the figure, that there were 3 peaks of which two were distinct. The distinct peaks occur during June and December recording 157.6 and 166.5 cysts per host respectively. The smaller peak occurring during August recorded 95.1 cysts per host. The seasonal occurrence of cysts on prawns also indicated that the intensity of cysts were more during monsoon (78.3), slightly less (68.4) during post monsoon and least during summer (16.8).

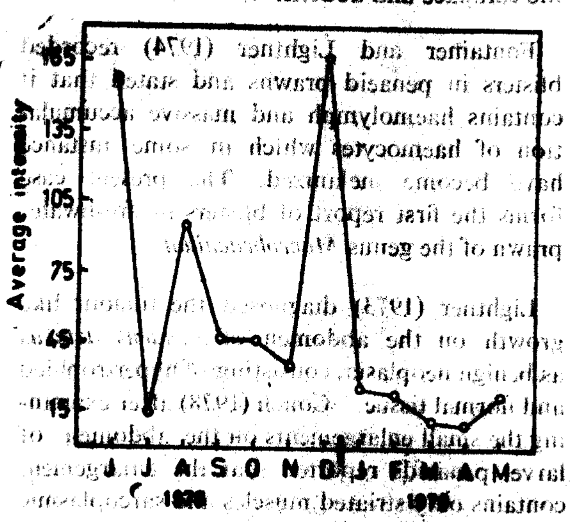

Fig. 5. Average intensity of infestation of protozoa on *Macrobrachium equidens* according to different months.

Isopod

The bopyrid isopod that attacks the branchial chamber of *M. equidens* is belonging to the genue *Probopyrus* (Giard et Bonnier). Of the total prawns examined, only 20 (6.9%) were infected and thus the infestation was not severe. The infected prawns were ranging a length of 25 mm to 52 mm in size. The cephalic region of the parasite was directed backwards and the ventral side was in close contact with the gill filaments.

The presence of the parasite was clearly evident from the conspicuous swelling of the lateral side of the carapace of the host (Plate I C). As a result of the attachment of the parasite the gills were highly compressed and in some cases a portion of the gill filaments were thrusted outside. In general the infected prawns appeared to be thin and emaciated. Further, in the present investigation the infestation was observed to be restricted to smaller sized prawns.

Blisters

Occurrence of blisters on the branchiostegal region of the carapace, ventral portion of the abdominal pleural plates and uropods have been noted quite frequently. The blisters were filled with fluid. The normal shape of the gill cover, pleural plates and uropods was lost due to the presence of blisters. Apart from this condition the prawns appeared to be quite normal. The cause of blister was not known.

Tumour

A single tumour on the lateral side of the carapace was noted (Plate I D). The swelling was conspicuous and in fresh condition the colour was reddish brown. The cause of the tumour was not known.

Discussion

Case reports of black spot disease on freshwater prawns of the genus *Macrobrachium* were much limited. Miller (1971) while describing the fishery and biology of the freshwater prawns of the genus *Macrobrachium* from the Lower St. Paul River, Liberia reported a very high incidence of blackspot disease on the exoskeleton of *M. vollenhovenni*. He had reported 91.3 per cent infestation and stated that the infestation occurred in all sizes and severe infection on larger forms. But in the present investigation a different picture was noted on *M. equidens* in that the infestation was more on medium sized prawns of length group (52 - 71 mm) and less in larger individuals (72 - 91 mm) and (92 - 111 mm) and absent in smaller forms of lengths less than 52 mm. A more prevalent infection was reported on *M. rosenbergii* by Dugan *et al.* (1975) and Johnson (1978).

Various species of bacteria were isolated from the black spot disease. Cook and Lofton (1973) stated that the mechanical injury to shrimp that results in the breakage in the normal cuticle probably plays an initiating role in the genesis of black spot disease. Dugan *et al.* (1975) was of the opinion that the chitinoclastic bacteria attack the damaged part and the secondary infection was by fungus. Delves—Broughton and Poupard (1976) isolated species of *Beneckea, Pseudomonas* and *Aeromonas* of which *Beneckea* predominated from the shell lesions of *M. rosenbergii*. Johnson (1978) was of the opinion that species of *Pseudomonas, Aeromonas, Acinetobacter* and *Vibrio* are generally encountered while examining the shell lesions. In the present study the organisms isolated from the black spot infection from exoskeleton of *M. equidens* were *Pseudomonas, Bacillus, Aeromonas* and *Serratia* in the order of predominance.

The present study with reference to sex, clearly revealed that the males were more susceptible to microbial infection (Bacteria and Protozoa). Further it has been observed that the microbial infestation was more during monsoon less during post monsoon and least during summer. In this regard it is worthwhile to mention that during rainy season higher land drainage leads to heavy accumulation of terrestrial organic matter which results in immense accumulation of the microbial populations in estuaries. The occurrence of micro-organisms in such environment may lead to heavy infestation.

Miller (1971) stated that the infestation was not restricted to the exoskeleton only but affected the underlying tissue also. A corresponding observation was made during the present study in that the gills and the abdominal muscles were affected when the infection was much severe on the carapace and abdomen.

Fontainer and Lightner (1974) recorded blisters in penaeid prawns and stated that it contains haemolymph and massive accumulation of haemocytes which in some instance have become melanized. The present case forms the first report of blisters in freshwater prawn of the genus *Macrobrachium*.

Lightner (1973) diagnosed the tumour like growth on the abdomen of *Penaeus aztecus* as benign neoplasia, consisting of hypertrophied and normal tissue. Couch (1978) after examining the small enlargements on the abdomen of larvel penaeids reported that the enlargement contains only striated muscles and sarcoplasmic reticulam. The tumour observed in the carapace of *M. equidens* during the present study forms the first report on this line.

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STUDIES ON THE ENVIRONMENTAL CONDITIONS OF TIDAL PONDS IN THE RAMANTHURUTH ISLAND (COCHIN)

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ABSTRACT

Environmental characteristics of certain enclosures and tidal ponds in Ramanthuruth Island where prawns grow in abundance were studied. Various parameters such as temperature, salinity, pH, Eh, dissolved oxygen, nutrients, chlorophyll 'a', particulate organic carbon, etc. were analysed from four different ponds in the island. These studies showed that the environment is subjected to seasonal variations due to the monsoons. It is observed that the ponds are highly productive during the whole year ($>$70 μg/1 Chlorophyll 'a') with a high amount of particulate organic matter. Since these ponds are tidal, there was no depletion of oxygen in the overlying water as a result of oxidation. The results indicate that these ponds are highly suited for the culture of prawns.

INTRODUCTION

ABIOTIC FACTORS particularly chemical characteristics of the environment can exert profound influence on the growth and survival of aquatic organisms. There are a number of reports on the prawn culture practices in Kerala (Panikkar, 1937; Menon, 1954; Gopinath, 1956; Kesteven and Job, 1957; George *et al.*, 1968; George, 1974), but they are mainly concentrated on the biological aspects of their culture. The culture ponds are mostly extensions of the estuary and backwaters and are therefore subjected to wider variations in the environmental conditions as compared to the sea. A regular monitoring of the environmental conditions therefore becomes essential to understand optimum environmental conditions for the culture of prawns.

The tidal ponds in the Ramanthuruth Island in the Cochin Backwater afford an excellent opportunity to study the different environmental conditions that can be met in certain culture ponds in this region. They were therefore regularly monitored at fortnightly intervals for various physico-chemical factors, such as temperature, salinity, dissolved oxygen, pH, Eh and nutrient concentration of the waters. The study was conducted for 12 months from September 1978 to August 1979.

Ramanthuruth is a small island with an area of 18 ha. roughly, in the Cochin Backwater near the harbour entrance, of which 12 ha. is formed by a tidal pond regularly leased out by the Government for harvesting prawns (Fig. 1). Connected to this pond there are three other small tidal ponds in the area selected for the present study. These ponds are not leased out and hence regular fishing is carried out.

The hydrography of the ponds in the Ramanthuruth Island is largely influenced by the tides and the changes caused by the seasonal monsoons. As these pools are connected with the backwater the changes are brought about by the influence of the inshore waters as well as the river system in the upper reaches of the backwater. The tide in this area is semidiurnal with an average amplitude of about 1 m.

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Material and Methods

Water samples were collected at fortnightly intervals from the surface. As there was no difference in the surface and subsurface water characteristics, the subsurface samples were collected only at frequent intervals. After the collections of samples they were brought to the laboratory and the analyses were made within 2 hours after the collections. Standard procedures were used for the analyses of samples.

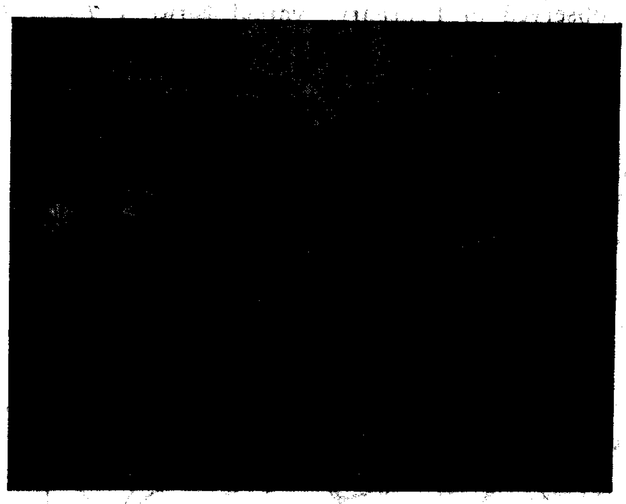

Fig. 1. Ramanthuruth Island showing various ponds.

Results and Discussion

Temperature

The temperature of the water in ponds varied between 27.5 and 34.0°C. During the SW monsoon season the temperatures were low. The minimum temperature was recorded during December-January. The low temperature observed during these months was due to the winter effect. In general higher temperature was recorded during the premonsoon season (March-May) and also during the postmonsoon season.

Higher temperature observed in ponds 2 and 3 in the month of July may be due to the shallow nature of the pond.

Salinity

The salinity of the pond water showed wide seasonal variation (Fig. 2). The values were low ($S < 5$‰) during June to November, when the SW monsoon was active. During this period freshwater flow predominated over the tidal flow in the surface layers of the backwater. The salinity values started increasing from December and the higher value (S>25‰) were observed in February and March. However, there was a slight drop in salinity during April and May. This may perhaps be due to the effect of the premonsoon showers, which is common during this period.

pH

The results showed that the pH of the water in the ponds were lower than the usual 8.0 to 8.3 of sea water. The values varied between 7 and 8.2. Higher values were recorded during the premonsoon season when the salinity values are high. Low pH values were confined to the SW monsoon period when the system was dominated with freshwater. The pH at bottom was

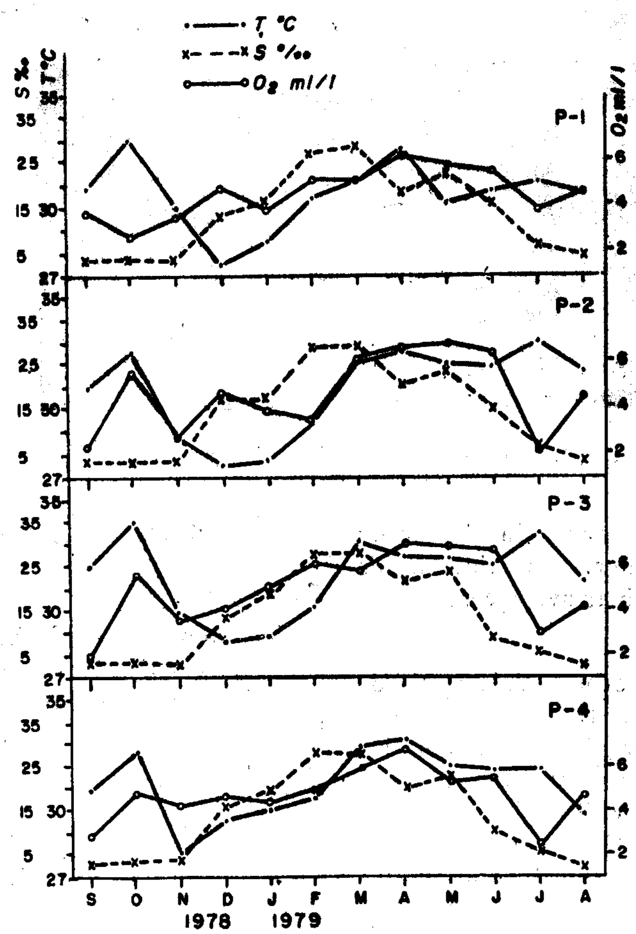

Fig. 2. Seasonal distribution of temperature, salinity and dissolved oxygen in ponds 1 to 4 of Ramanthuruth Island.

approximately the same as that near the surface.

Eh

The oxidation reduction potential exhibited only a narrow range of +100 to +140 mV throughout the surface layer. The bottom water Eh also did not show much variation and was similar to that of the surface. However, the bottom sediments in these ponds exhibited a variation from −245 to −120 mV indicating reducing conditions in the mud. But there was no smell of hydrogen sulphide excepting on a few occasions in the bottom sediments of pond 2.

Dissolved oxygen

The water in the ponds was well oxygenated with values varying between 2 and 7 ml/l (Fig. 2). High oxygen values were noticed during the premonsoon months (March to May). The dissolved oxygen content was relatively low (< 4 ml) during the SW monsoon period (June to October). The values steadily increased in the following months. As the system was relatively shallow the vertical variation in the dissolved oxygen concentration was negligible.

Nutrients in organic phosphate

Inorganic phosphate in the waters of all the ponds showed very high values (>2μg at/l) throughout the year (Fig. 3). Highest value was observed in pond 2. The phosphate levels showed a general increase during the SW monsoon period (June to October), excepting a fall in the concentration during the month of August in ponds 1, 2 and 3. The phosphate concentration in pond 2 was exceptionally high during these months. In pond 4 the seasonal variation in the phosphate levels showed a general decrease from the month of March to September unlike in other ponds. Afterwards the levels showed an increase during the following months, except in November and December.

Nitrate

Nitrate values in all the ponds varied between <1 and 15 μg at/l (Fig. 3). The annual distribution in the nitrate levels showed a general decrease during the months March to May and during September and October. Highest nitrate values were recorded during June and August and the values showed a decrease and afterwards an increase in the following months. The general pattern of monthly variation in all the ponds are similar.

Chlorophyll 'a'

While all the ponds in Ramanthuruth Island were highly productive the pond 2 appeared to be exceptionally rich in chlorophyll with values exceeding 300 μg/l. The chlorophyll 'a' values showed a maximum concentration during June to September, in all the ponds excepting the pond 2, where the chlorophyll was high throughout the year. In all the other ponds the minimum amount of chlorophyll 'a' was observed in May. High chlorophyll concentrations were usually observed with dense phytoplankton bloom of a single species like *Nitzschia*, *Skeletonema*, *Peridinium*, at different months of the year.

Organic matter

The organic matter in the ponds varied between 1 and 4%. Many of the bottom samples from the pond contained leaves and twigs of plants. The organic matter in the sediment was due to the incomplete oxidation of debris from plants, the leaves of which were blown into these ponds, apart from the contribution from the overlying water. The population living in the island is also contributing for fertilizing the pond by feeding the ducks in the pond

Retting the coconut husks leads to reducing conditions in the water and in the bottom sediments. But at no time of the year reducing condition of the water was observed.

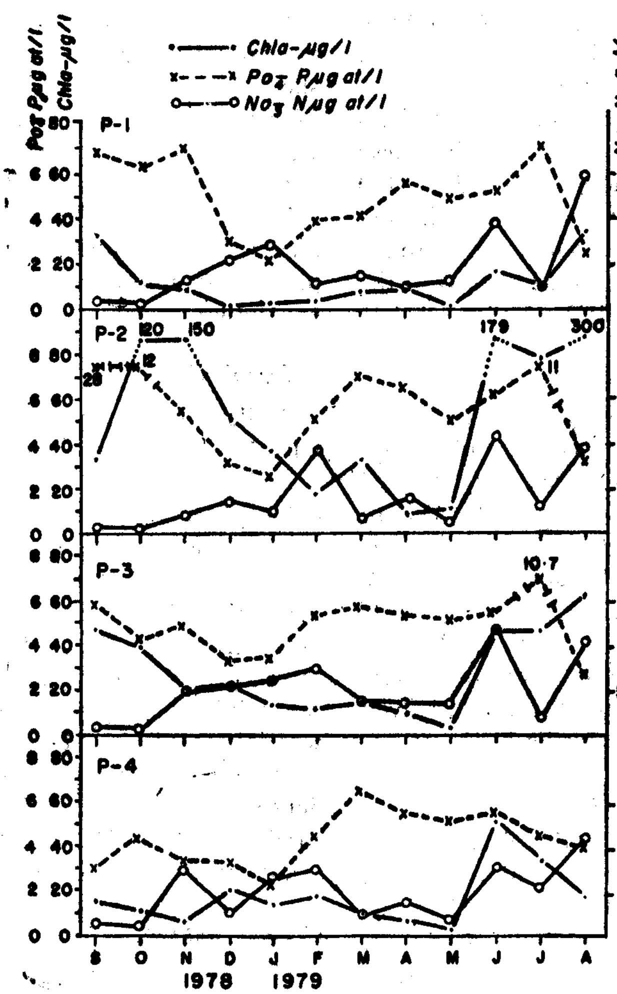

Fig. 3. Seasonal distribution of inorganic phosphate, nitrate—nitrogen and Chlorophyll 'a' in ponds 1 to 4 of Ramanthuruth Island.

As described earlier the smell of hydrogen sulphide in the mud was noticed at a few occasions in pond 2 but in other ponds it was absent.

REMARKS

The foregoing account clearly indicates that the cycle of events in the tidal ponds of Ramanthuruth Island was fairly regular. The temperature of the water was relatively low during the SW monsoon season when the rain was maximum and also during winter

Several workers (Williams, 1960; Zein-Eldin and Griffith, 1969; Venkataramaiah *et al.*, 1974; Sreekumaran Nair and Krishnan Kutty, 1975) have stressed the importance of temperature and salinity in the survival and growth of prawns. Although Rao (1973) did not observe the relationship between the distribution of larvae and the temperature conditions in the inshore and backwater regions, the peak abundance of larvae was noticed at temperatures between 28° and 30°C. During July to November the salinity of the water in these ponds were low (< 5‰) as a result of large influx of freshwater due to the monsoonal rains. But the salinity increased during the following months to values > 10‰ and it maintained till the month of June when the freshwater flow began. Williams (1960) has found that the juveniles of certain species of *Penaeus* survived better in higher salinities. Nair and Krishnan Kutty (1975) based on laboratory studies have found that the growth rate of *Penaeus indicus* is significantly high in salinity of 10‰ for postlarval stages and in salinity of 30‰ for juvenile prawns. In the Ramanthuruth area, when the season for impounding the postlarvae in the fields begin the salinity is relatively low which gradually increases as the season progresses which also suits the increasing salinity optima of the growing prawns.

The dissolved oxygen of the water in all the ponds was never below 30% saturation during different months of the year. Relatively lower oxygen saturation values (< 3 ml/1) were observed when the system was freshwater dominated and during rest of the months the oxygen content was more than 4 ml/l indicating well oxygenated condition of the environment. The waters in the pond were rich in nutrients with inorganic phosphate values greater than 2 μg at/1 throughout the year and of nitrate values more than 1 μg at/1. The distribution of nutrients therefore indicated that the primary production in these ponds were not nutrient limited. The nutrient concentration in these waters were mainly influenced by the marine waters and by the freshwater discharge as suggested by Sankaranarayanan and Qasim (1969). As the system was shallow the regeneration and the cycling of nutrients was also largely reflected by the high values in the overlying waters. The phytoplankton production in these ponds was also high throughout the year (Fig. 3). The zooplankton population in these ponds was low during most of the months of the year (Haridas, per. comm.). Therefore the high phytoplankton production may be going waste in the overlying water and getting deposited in the bottom. Relatively high organic matter (> 4%) of the mud with a calorific content > 200 cal/g dry wt lends support to this. The low redox potential of the bottom mud also indicated the high organic content of the mud. Qasim *et al.* (1969) have also noticed a large surplus of primary production which falls to the bottom as detritus in the Cochin Backwater. The calorific content of the detritus has been estimated by Qasim and Sankaranarayanan (1972) to be from 200 to 500 cal/g dry wt. 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 experiments conducted in the laboratory. They found a gross growth efficiency of 10.5 to 35.2% and the assimilation efficiency in the order of 93%. These ponds can therefore support a rich bottom fauna, an important source of food for prawn, besides detritus.

The present observations clearly indicate that these ponds are highly productive and suitable for culturing prawns. The environmental conditions and the high organic production are conducive for their fast growth and for maintaining a high biomass.

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ENVIRONMENTAL CHARACTERISTICS OF THE SEASONAL AND PERENNIAL PRAWN CULTURE FIELDS IN THE ESTUARINE SYSTEM OF COCHIN

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ABSTRACT

The paper embodies the results of investigations conducted to study the environmental characteristics of the prawn culture fields in the estuarine system of Cochin from Azhikode in the north to Kumarakam in the south including the Vembanad Lake. Primary productivity and related hydrobiological parameters of the water have been studied from 50 stations during December '77 to May '78 when the prawn and other brackishwater fishes are cultivated in the fields lying adjacent to the ecosystem. In addition, the epifauna, benthic fauna and chemical constituents of the mud of these fields have also been analysed and results presented. Significant regional variation in the case of primary production, faunistic composition of epifauna and benthos of these prawn culture fields were observed. The chemical composition of the mud also evinced distinct regional variations. Based on these productivity parameters, an attempt has been made to categorise the various prawn culture fields existing in the estuarine system.

INTRODUCTION

THE DYNAMIC ENVIRONMENT of the estuarine system of Cochin and the connected backwater plays a significant role in the fishery of the area in general and the prawn fishery in particular. Due to the high demand for prawns in the recent years, efforts are being made to augment their production through prawn/shrimp farming. In Kerala, about 5120 ha of fields are utilised for prawn culture, of which about 3500 ha are situated in and around the Cochin estuarine system. Although several publications (Qasim *et al.*, 1968, 1969; Qasim and Gopinathan, 1969; Sankaranarayanan and Qasim, 1969; Qasim and Sankaranarayanan, 1972; Gopinathan *et al.*, 1974; Nair *et al.*, 1975; Pillai *et al.*, 1975; Madhu Pratap and Haridas, 1975) provide informations on the hydrobiology and ecology of the Cochin Backwater and adjacent areas, detailed account dealing with the productivity of the prawn culture fields situated in the estuarine system is lacking. The main objective of this study is to assess the productivity of the seasonal and perennial fields at various trophic levels through a baseline survey with productivity techniques and from other related parameters in assessing the biogenic capacity of water in the fields, a pre-requisite in determining the stocking strategies and in the evaluation of the production in the culture system.

The authors are grateful to Dr. E. G. Silas, Director for suggesting this topic for study and also for the encouragement. They are also thankful to Dr. P. Vedavyasa Rao, for critically going through the manuscript and offering improvements. Thanks are also due to Smt. K. K. Valsala of this Institute and

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Material and Methods

The area of investigation includes the extensive estuarine system from Azhikode in the north to Kumarakam in the south including the Vembanad Lake enclosing a large number of prawn culture fields, both seasonal and perennial ones. Fifty stations (32 seasonal and 18 perennial fields) were covered during the prawn/fish culture period of December 1977 to May 1978 (Fig. 1). Although culture practice is extensively carried out in the entire system, at Thanneermukkom, virtually no prawn culture fields are in operation in the zone south of the barrage since its commissioning in 1976. In the seasonal fields, paddy is cultivated from May to August. After the harvest of paddy, juvenile prawns brought in by the tidal currents are allowed to enter and grow in the fields and are periodically harvested. Since the perennial fields are deeper than the seasonal ones, only prawn culture is possible which is carried out throughout the year. The average depth of the seasonal fields is about 1 m whereas the perennial fields are 2-3 m deep.

Light and dark bottle oxygen technique has been used to estimate the primary production with occasional cross checks by ^{14}C technique. The production per unit volume has been computed using PQ 1.25. The sampling has been done at the surface only and the incubation has been carried out under identical conditions of light and temperature. In view of the limited depth of the water bodies, it was not felt necessary to conduct sampling at various depths. As the light penetration takes place upto the bottom, there is not much limitation regarding the available energy for photosynthetic activity. Hydrological properties such as salinity, oxygen and nutrients (Nitrite, Nitrate, and Phosphate) were determined by standard methods (Strickland and Parsons, 1968). The epifauna was collected by filtering a known volume (100 l) of water through sieves of 0.097 mm and 0.069 mm. Samples of epifauna and suspended detritus were collected by filteration method from the fields investigated. Mud samples were collected to analyse the faunal index of benthic organisms as well as to estimate the chemical composition such as organic carbon, pH, phosphate and total soluble salts. Estimation of the amount of organic carbon in the mud sample was done by the chromic acid oxidation method. For the convenience of presenting the results, the stations located in the northern and southern areas of Cochin are discussed separately.

Results

The data on the various physico-chemical properties of the water along with that on the primary production is presented in Fig. 2.

Hydrological properties

Temperature: The temperature of the ambient water of the fields recorded a difference of 6°C, ranging from 26.8 to 33°C (Fig. 2 g) during the period of survey (December-May). It has already been established that in the Cochin Backwater and adjacent areas, temperature has little significance in the production of organic matter (Qasim *et al.*, 1969).

Salinity: In contrast to temperature, wide range of salinity variations were observed which ranged from 1-27‰ in the different fields investigated (Fig. 2 f). Since the northern region of the estuary has two connections with the sea, relatively high salinity values were recorded in the fields of this zone.

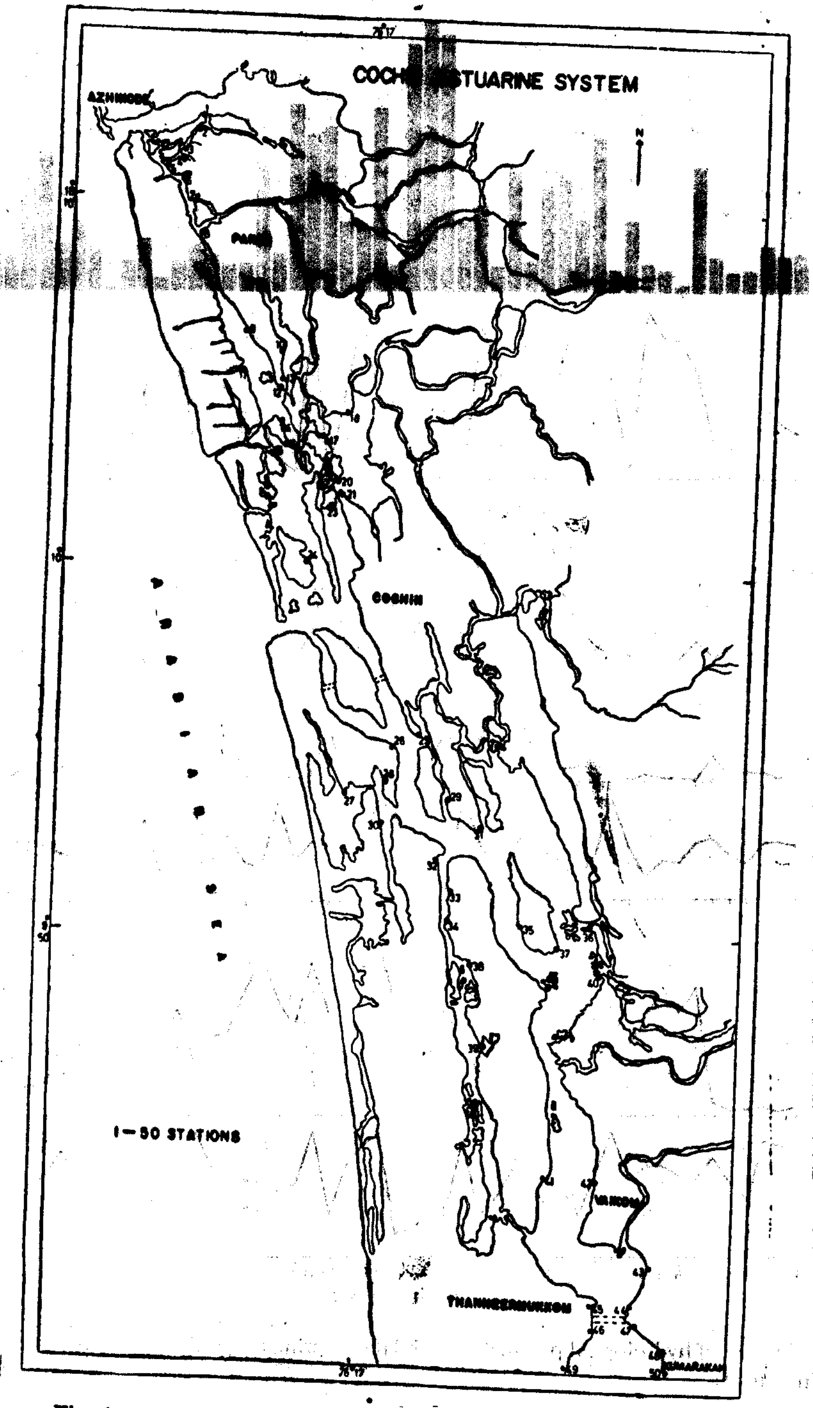

Fig. 1 Location of stations in the Cochin estuarine system.

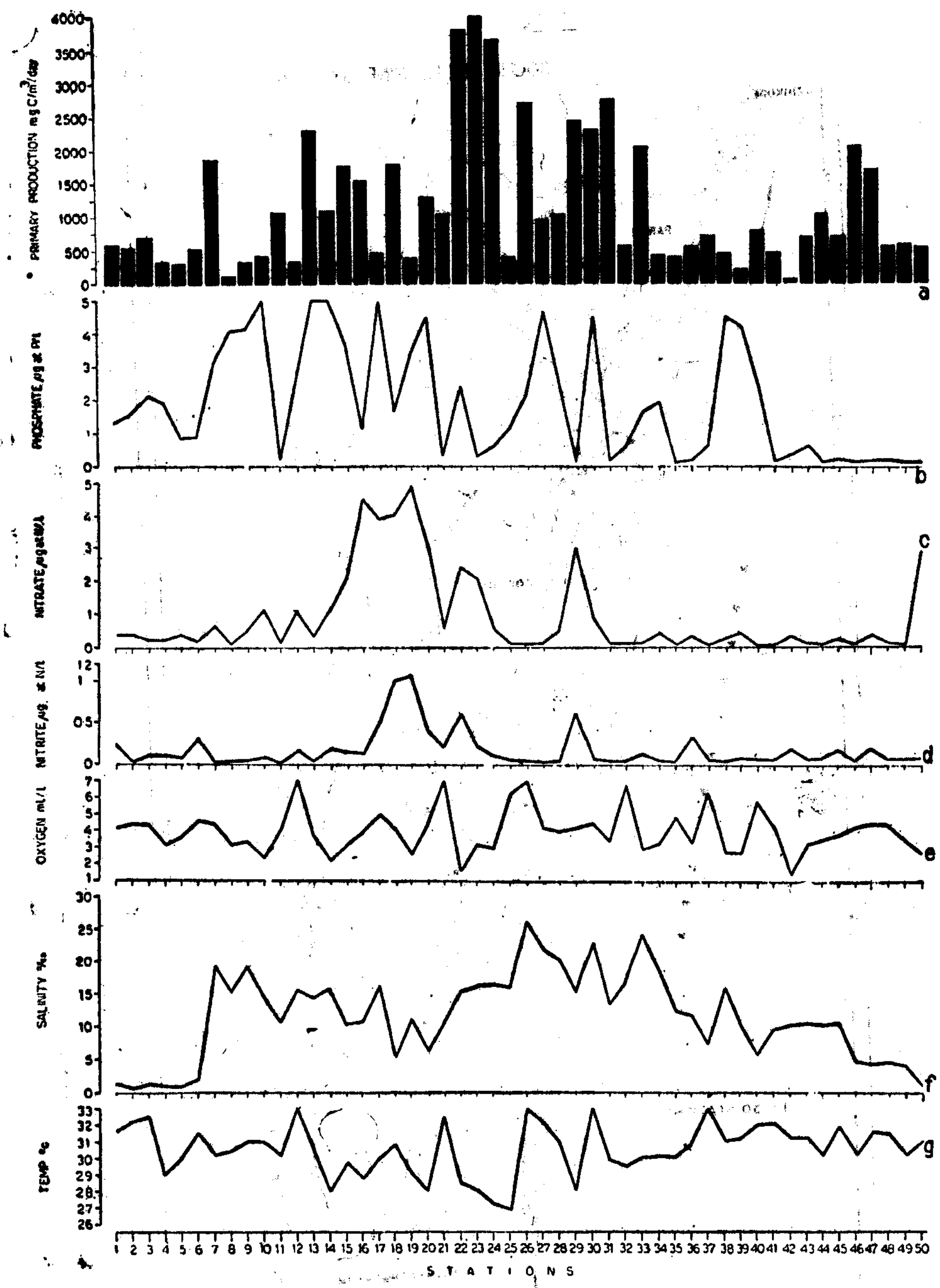

Fig. 2. Distribution of hydrological parameters and data on primary production in the different prawn culture fields.

Similarly low values were recorded in the fields adjacent to the Vembanad Lake. However, the effect of interstitial salinity on the survival and growth of the organisms will be of much significance in some of the fields located away from the bar mouth. The variation in salinity has already been reported from the entire estuarine system (Josanto, 1971; Qasim *et al.*, 1972; Gopinathan *et al.*, 1974; Pillai *et al.*, 1975).

Dissolved oxygen: The dissolved oxygen content of the water in the prawn culture fields showed distinct regional variations. The fields of the northern region have high or optimum values (4-6 ml/l) as compared to the southern regions (2-3 ml/l) (Fig. 2 e). Although the dissolved oxygen content has no direct role in the production of organic matter in the estuary, it is an index of the metabolic activities of the entire community comprising producers as well as consumers.

Nutrients: During the present investigation, nutrients such as nitrite, nitrate and phosphate were estimated from the water samples. The nitrite content of the water was very low (< 1 μg at N/l) in almost all the stations and ranged from 0.2 to 1.10 μg at N/l (Fig. 2 d). However, wide variations were noted in the nitrate values, ranging from 0.24 to 4.94 μg at N/l in the fields investigated (Fig. 2 c). Both nitrite and nitrate showed moderate to high values in the fields located in the middle regions of the estuary. The fields situated in the northern and southern regions had very low values of nitrogenous compounds. The phosphate values ranged from 0.06 to 5.80 μg at P/l (Fig. 2 b). As in the case of nitrate, the phosphate also showed high values in the fields of the middle zone as well as in a few stations of the northern zone. The observed values of nutrients showed an increasing trend in the fields located in the middle and northern regions as compared to the fields located in and around the Vembanad Lake.

Primary Production: The productivity values obtained during the survey period of December—May of all the stations were plotted in Fig. 2 a. The measurements indicate that the entire area covered during the investigation can be classified into 3 categories; *viz.* highly productive (> 1500 mgC/m²/day), low productive (<500 mgC/m²/day), and moderately productive zones (500-1500 mgC/m²/day). The prawn fields in the middle region of the estuary which showed high rate of production as compared to the extreme northern and southern regions, (Fig. 1, stations 7, 13-16, 18, 22 - 24 in the northern half and stations 26, 29 - 31, 34 in the southern half). Moderate values were observed in the northern and southern extremities of the estuary especially at stations: 1, 3, 6, 11, 20, 21, 27 - 28, 33, 37 - 38, 44 - 45 (Fig. 1). Low values were observed in the prawn fields where there is direct connection with the main land, such as the stations: 4-5, 8-10, 12, 17, 19 of the northern region and stations 25, 32, 35-36, 39 - 40, 42 - 43 in the southern region. However, the fields near Thanneermukkom Bund showed rather high values when compared to the other fields located in the interior regions of the northern half of the estuary.

Among the prawn fields, the seasonal fields are found to be more productive than the perennial ones. This is reflected in the occurrence of more seasonal fields in the northern regions of the estuary where the productivity parameters showed an increasing trend. Based on the data on primary production, it has been possible to classify the different regions of the prawn culture fields as follows:

1. A highly productive area north and south of Cochin bar mouth where there

is a constant incursion of seawater and influx of river water. In such a dynamic environment, due to high replenishment rate, the water is never 'old'. Similarly, a belt of high productive area is found in the prawn fields lying adjacent to Azhikode bar mouth where there is freshwater discharge from the Chalakudy river. During the period of freshwater discharge, high concentrations of nutrients occur with great variations within the system. Large quantity of organic matter are brought into the estuary through the land run off. These are probably decomposed at the bottom and as a consequence seem to have a marked influence on the nutrient distribution.

The waters in between the highly productive zones, *i.e.* between Cherai (Stn. 7) and Vallarpadam (Stn. 24) on the northern half of the estuary and the waters in the region of Vembanad Lake are found to be moderately productive. The effect of Thanneermukkom Bund, on the basic productivity of the water on either side seem to be insignificant, though in the overall population structure, there has been significant variation.

The water bodies on the hinter-land around Vaikom in the south form a low productive area as observed earlier by Nair *et al.* (1975). This is probably because the incursion of nutrient-laden water is highly restricted in this zone which may be limiting the primary production. In such areas, it would be necessary to provide artificial feeds or other additional inputs to supplement the basic productivity.

Epifauna and suspended detritus

Assessment of the epifauna, the organisms occupying the secondary level of the food chain and detritus, the biogenic and non-biogenic material undergoing various stages of microbial decomposition, form a major pre-requisite in the studies of organic productivity of a given area. With this in view, a survey of the distribution of epifauna and suspended detritus, occurring regularly in the plankton has been carried out in certain selected prawn fields (Fig. 3) in the estuarine system as part of the present study and the results are presented here.

Faunistic composition of the epifauna indicate that the following groups/species formed the major components in the order of their abundance: Rotifers, copepods and copepodites; copepods such as *Oithona* spp., *Acartia* spp., *Pseudodiaptomus* spp., *Acartiella* spp., *Diaptomus* spp., nauplii of other crustaceans, bivalve larvae, radiolarians, fish larvae, nematodes, polychaetes, fish eggs, cladocerans, tintinnids and harpacticoid copepods. The percentage composition of different groups shows that rotifers constitute more than 50% of the epifauna in almost all the fields, followed by copepod nauplii and copepodites (2-8%). Other groups listed above formed only a minor portion in different fields (<2%).

The total biomass of epifauna was relatively high in the northern area (Stns. 1-5) as compared with that in the middle region of the estuary between stations 15 and 41. In the vicinity of Thanneermukkom (Stn. 46), relatively high values of biomass have been recorded. Further, analysis of the pattern of quantitative distribution of the faunal elements indicates that they are numerically abundant in the vicinity of the stations 5 and 7 in the northern sector and around stations 36, 46 and 49 in the southern region. The constituent fauna in the area between stations 15 and 30 were found to be of a minority in the collections.

Direct correlation between primary production and the quantitative distribution of epifauna was difficult to derive at since, the faunal elements were poorly represented in the fields located in the vicinity of Cochin, both to the south and north, where high rates of primary production were recorded. Similarly the quantitative distribution of epifauna showed a negative correlation with salinity (Fig. 3 b) especially in to fields situated around Cochin. However, rotifers showed distinct abundance in most of the fields where gross production rates and quantity of suspended detritus were relatively high.

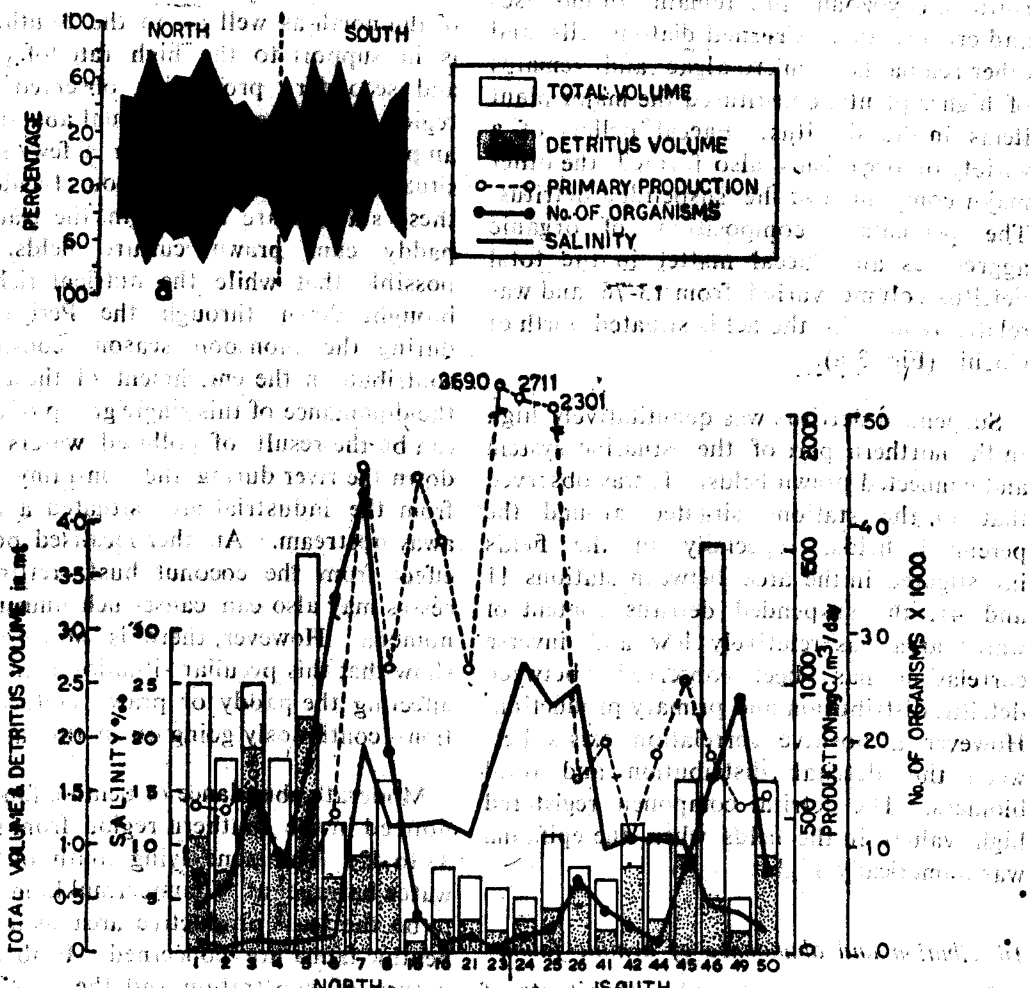

Fig. 3. a. Detrital volume (%) observed in the stations in the northern and southern zones of the estuarine system and b. Distribution and abundance of epifauna and suspended detritus in relation to salinity and primary production.

Examination of the suspended detritus (which occurs regularly in the plankton and can be differentiated from the settled detritus) revealed that it was of different size and shapes and, basically composed of silt or sand. Organic matter, such as the remains of animals and plants was found to be deposited around such particles. Major groups of identifiable organisms include foraminifera, nematodes, polychaetes, rotifers, bryozoans and remains of molluscs and crustaceans. Crushed diatom cells, and other remnants of micro-algae and remains of higher plants, constituted the major plant items in the detritus. Faecal pellets of a variety of organisms also formed the other major component of the suspended detritus. The percentage composition of organic aggregates and faecal matter in the total detritus volume varied from 13-76, and was relatively high in the fields situated north of Cochin (Fig. 3 a).

Suspended detritus was quantitatively high in the northern part of the estuarine system and connected prawn fields. It was observed that in the stations situated around the perennial fields, especially in the fields investigated in the area between stations 11 and 41, the suspended detritus content of water area was relatively low and inverse correlation has been observed between detritus distribution and primary production. However, a positive correlation exists between the detrital distribution and total biomass. The detrital component registered high values in the fields when the epifauna was numerically high.

Distribution and abundance of benthic fauna

Since prawns are primarily inhabitants of the benthic region, the distribution and abundance of the benthic population is of great significance when the ecological conditions for prawn culture are assessed and evaluated. It is well known that benthic population represents an important link in the trophic cycle in this type of ecosystem.

The dominant benthic fauna were found to be molluscs (bivalve and gastropods) followed by polychaetes, amphipods, kinorhinchids, isopods and cumaceans. The general pattern of their distribution indicates an abundance in stations located in the immediate vicinity of Cochin bar mouth, both to the north as well as to the South. This is in support to the high rate of primary and secondary production observed in this region. However, an unusual abundance of amphipods was noticed in a few stations situated north of Cochin harbour. Incidentally, these stations are located in the traditional paddy cum prawn culture fields. It is possible that while the nutrient rich water brought down through the Periyar river during the monsoon season, considerably contribute in the enrichment of these fields, the dominance of this single group of animals can be the result of polluted waters coming down the river during the non-rainy seasons from the industrial area situated a few km away upstream. Another localised pollution effect from the coconut husk retting processes may also can cause such unusual phenomena. However, there is no evidence to show that this peculiar situation is in anyway affecting the paddy or prawn culture operations continuosly going on in this area.

Moderate abundance of benthic fauna were noticed in the southern region from stations 33 to 42. The zone lying south of the salt water barrage at Thanneermukkom appears to be the least productive area as far as the benthic fauna are concerned. Probably, the nature of substratum and the almost fresh water conditions prevailing and other ecological conditions (*e.g.* the large quantity of floating weed *Salvinia* sinking to the bottom on decay) are the contributing factors for such a situation. However, from the available data, it can be said beyond doubt that the northern half of the estuarine system and connected prawn culture fields are more productive as far as the benthic fauna are concerned (Fig. 4). The trend revealed from preliminary survey was carried out to estimate the organic carbon, phosphate, pH and total soluble salts. The effect of large scale river discharge and the organic matter reaching the paddy fields and estuarine areas were reflected on the data gathered (Fig. 5).

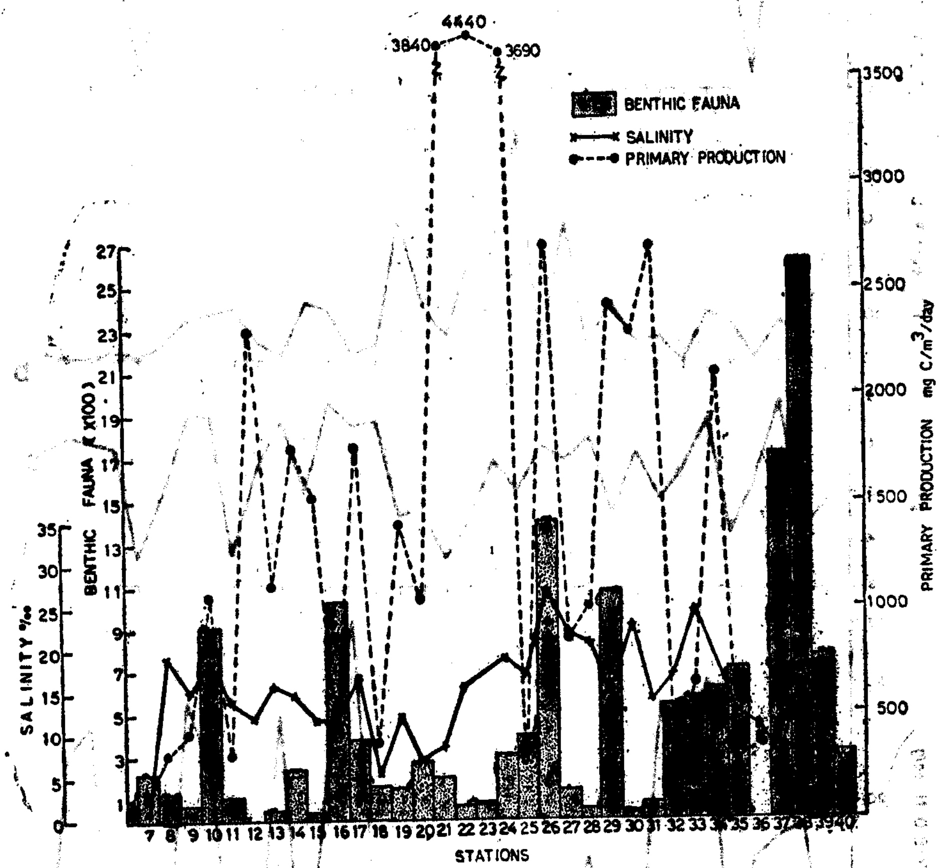

Fig. 4. Benthic fauna of the selected stations in relation to salinity and primary production.

other aspects of investigations in this study also supports this point.

Chemical composition of the sediment

Since the chemical composition of the sediment, especially the carbon content is an index of the input to the ecosystem as well as the overall productivity of the environment, a

Organic carbon: Comparatively high values of organic carbon (22-35 mg/g) were observed at a few stations which are located in the proximity of river water entering the backwaters. The advantageous position of these fields in receiving a constant supply of organic matter may be the reason for this phenomenon. In the fields where the soil

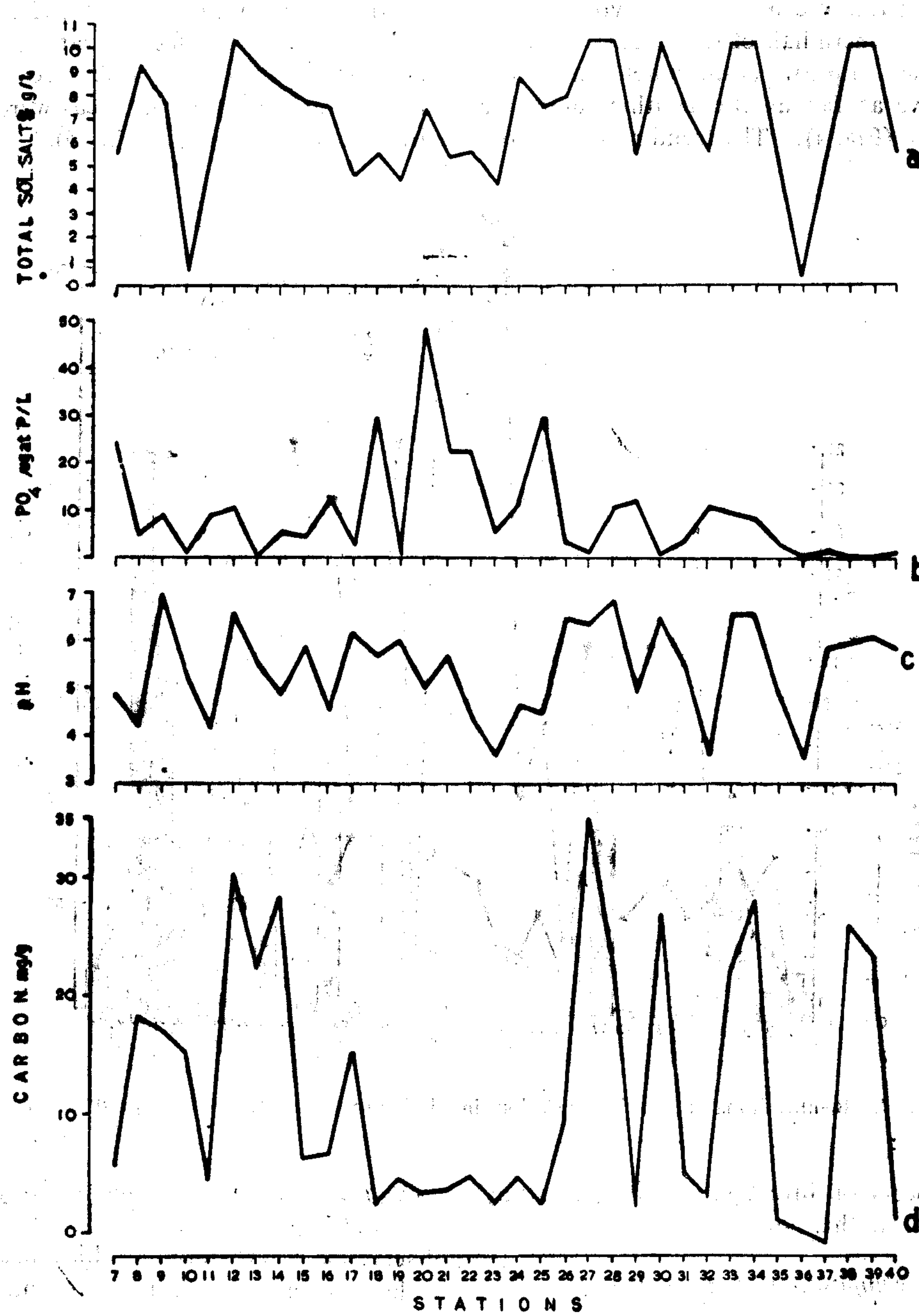

Fig. 5. Chemical composition of the mud from prawn culture fields.

composition was sandy, the organic carbon content was invariably low (<10 mg/g) while in areas where the substratum was of an alluvial nature, the carbon content was moderately high (20 mg/g). This is an apparent reason for high rate of production recorded in the fields around Cochin where the soil is alluvial in nature. Incidentally, the seasonal prawn/paddy culture fields were observed to have high organic content in the sediment, apparently due to the decay of roots and stems of rice plants after the harvest, adding thereby a good amount of organic matter to the soil. The spatial variation of the organic carbon content of the mud sample studied are presented in Fig. 5 d. The periodic enrichment of these fields by river water during the rainy season may also be contributing to this phenomena.

pH: The pH of the sediments indicated a range between 3.5 to 7.0. However, in the majority of stations, the range was between, 5 and 7.0 (Fig. 5 c). Certain low values were recorded in the southern-most stations, obviously because of the effect of large scale decomposition of weed deposits in the area.

Phosphate: Compared to the phosphate content recorded in the ambient water (0-5 μg at P/l), in the sediments fairly high concentrations (0-50 μg at P/l) were recorded, especially in the middle region of the study area (Fig. 5 b). The high rate of manuring in the adjacent agricultural fields may be the causative factor for this phenomena.

Total soluble salts: The total soluble salts in the mud samples do not show much variations, except at one station (Stn. 10). The values ranged from 0.60 g/l to 10.40 g/l. However, most of the stations have moderate values (5-10 g/l) and the data did not reveal any regional variation of this parameter (Fig. 5 a).

Discussion

It is well known that the yield of living resources to man from any water body is closely related to the primary productivity of the waters. In the marine environment, a fraction (about 10-20%) of the productivity of one level is transferred to the next. But in the case of lakes and confined waters where prawns constitute the predominant yield such a prediction is rather untenable. However, some meaningful conclusions could be drawn by examining critically various productivity parameters such as rate of photosynthesis, availability of nutrients and energy and also the quantum of epifauna and detritus of the concerned ecosystem.

The productivity in lakes as well as in freshwater bodies is a function of the nutrient supply. In these environments, nutrient availability is largely the result of sediment composition as well as variations in the surrounding land use and resultant run off. The river input also contributes to this significantly. However, beyond the critical concentration required for phytoplankton production excess nutrients may be just assimilated without further plant growth (Gerloff, 1969) which has been termed as 'luxury consumption' (Hendersen *et al.*, 1973) by the phytoplankton.

Figure 2 gives the primary production in terms of carbon per day as well as the basic nutrients that govern the rate of turn over. It may be seen that the phosphate in the ambient water and in the mud as well as organic carbon which is an index of the available nitrogen supply do not show direct proportionality with primary production values. The critical concentration factor of the nutrient supply may probably be the reason for this.

Based on productivity and related parameters a certain amount of zonation can be derived. The present survey substantiates the earlier observations (George *et al.*, 1968; George, 1974; Pillai and George, 1974) that the fields located in between Cochin and Azhikode bar mouth is relatively a more productive area. The ecological advantage of having two openings to the sea within a short distance through which there is a regular incursion of saline water and also the periodical enrichment from the run off from Periyar river to this area can be the causative factor for this phenomenon.

Based on organic production, the estuarine system of Cochin extending from Azhikode to Alleppey, covering an area of about 300 sq. km has been classified into low, moderate and high productive areas—where production exceeds 1500 mgC/m^2/day is being highly productive and less than 500 mgC/m^2/day being low productive and areas between these two rates of production being considered as moderate. High rate of production has been recorded at the regions south and north of Cochin bar mouth where the influx of the inshore water is relatively greater. So also where there is the influx of freshwater from river discharge, the rates are comparatively high. The estuarine region, where there is least influence either from replenishment by the 'new water' or influx of freshwater, the rate of production is low.

It is also observed that the seasonal fields are more productive than the perennial fields. Due to paddy cultivation and also by the regeneration process of the nutrients in the sediment, the organic compounds in the benthic region increase. The nutrient content of the water of the seasonal fields, located in the northern region of the estuary show higher values as compared to the southern region.

The total biomass of the epifauna was relatively high in the northern part of the estuarine area and in some fields in the southern sector. Numerical abundance of organisms in the fields also followed the same pattern of distribution. No positive correlation between productivity and salinity and abundance of epifauna as well as benthic fauna has been observed during the present survey. However, the preponderance of rotifers in the epifauna over other groups in the areas located near seasonal paddy-cum-prawn fields indicates that the fields are rich in organic matter. Result of the investigation on the chemical composition of the sediments presented (Fig. 5) in this account also support this assumption.

In the fields located far away from the bar mouth as well as those fields which do not have proper inlet canals, circulation of water is a major factor. In fact the higher productivity of shallow water bodies can be related to continuous stirring of the bottom by waves and water circulation. In addition, large inputs of particulate organic material or detritus is also important. Detritus may be formed either by internal supply from remains of phytoplankton, other rooted vegetation and dead zooplankton. It is also formed partly by mineralization of organic inputs from man-made sources. The tidal movement keep this detritus matter in suspension for a prolonged period.

The importance of detritus as food of estuarine and nearshore organisms has been documented by earlier authors (Fox, 1950; Darnell, 1961; Newell, 1965). Nutritional value of suspended detritus has been reported by Parsons (1963) and Kenchington (1970). Qasim and Sankaranarayanan (1972) studied the organic detritus at a station in the Cochin Backwater and concluded that the detrital sedimentation in the estuary attains its maximum during April-June period. They also stated that detritus form a major portion of the seston but phytoplankton productivity constitutes only 0.1 to 1.0% of the settled detritus. Results of the present study on the quantitative relation between phytoplankton production and suspended detritus indicate that the detritus is not wholly of phytoplankton origin. As stated earlier, it mainly contained the organic aggregates and faecal pellets of a variety of organisms. However, detrital components showed a positive co-relation with the total biomass and the numerical abundance of organisms. It has been observed that normal abundance of detritus occurs in environments which have a high organic load (Qasim and Sankaranarayanan, 1972). Their accumulation in the vicinity of prawn fields situated in the southern and northern zones of the estuarine system, might have been contributed by the organic material brought down by the rivers in these regions and land run-off from the adjacent areas.

Thus, the amount of detritus, nutrient level as well as the magnitude of primary production together could be taken as the criteria for estimating the stocking potential and also to determine the other inputs required for taking an optimum sustainable yield from the seasonal and perennial fields. It may be pointed out here that the yield of fish or other resources have been estimated from productivity and certain other easily measurable parameters by developing what is termed as 'morpho-edaphic index' (Ryder, 1965) which has been successfully applied in certain African lakes (Hendersen *et al.*, 1973). It may therefore be suggested that fields with a productivity rate of 2000 $mgC/m^3/day$ and having a relatively high detrital concentration could be stocked intensively without any additional inputs as fertilizers. Other fields with varying levels of productivity would require addition of organic material or inorganic manure, the requirement of which should be carefully calculated on the basis of the productivity of an ecosystem already available.

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FISH AND SHELLFISH SEED RESOURCES OF KALI ESTUARY ALONG WITH A NOTE ON THE MARICULTURE POTENTIALITIES IN UTTARA KANNADA

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ABSTRACT

The Kali Estuary, an important estuarine system of Uttara Kannada District of Karnataka has been studied for its seed resources—their occurrence, distribution and abundance. The most important seeds that are available in plenty are those of *Penaeus indicus, P. monodon, Metapaenaeus dobsoni, M. monoceros, Mugil cephalus, Scatophagus argus, Etroplus suratensis* besides the spats of edible oyster *Crassostrea gryphoides*, the mussel *Perna viridis* and the clam *Meretrix meretrix.*

The paper indicates the scope for exploitation of the seeds for profitable farming in the lowlying areas, mud flats and the mangrove swamps around Kali Estuary and the potentialities of mariculture in other estuarine systems of the rivers Gangavali, Aghanashini and Sharavathi in the District.

INTRODUCTION

IN INDIA the present rate of fish production is very much insufficient and requires to be greatly increased, which however is not possible only by capture fishery. It is in this context that in recent times the Culture fishery has become the most effective and promising avenue of getting additional source of fish food. India with a coastline of about 5,600 km offers rich culture potentialities as evidenced by the existence of vast stretches of estuarine areas (Jhingran and Gopalkrishnan, 1973). It is these estuaries that constitute the nursery grounds for almost all euryhaline organisms thus forming seed reserves for culture practices. Further, there is also a good scope for developing coastal aquaculture by way of utilising the coastal swamps, tidal flats, backwaters and tidal inlets (Jhingran and Natarajan, 1970). With this in view a survey was undertaken in Uttara Kannada, a prominent coastal district of Karnataka to study the culture potentialities in terms of available seed resources of the Kali Estuary and the existing culturable biotopes during the period from December 1978 through December 1979.

MATERIALS AND METHODS

In order to study the distribution of seeds, six stations *viz.*, Kodibag creek, Mavinahole creek, Sunkeri, Hottegali backwaters, Chittakula and Kanasageri are selected for the present study (Fig. 1). The seeds were collected using the drag net (12′ × 6′) of mesh size 2 mm.

SEED RESOURCES OF KALI ESTUARY

Kali Estuary in contrast to the other estuaries of the District *viz.*, Gangavali, Aghanashini and Sharavathi lying in the coastal taluks of Ankola, Kumta and Honnavar respecting occupies a foremost position as regards the fishery resources and development potentials. The seed potentialities of Kali Estuary were extremely rich and poly-specific. The mullets, particularly *Mugil cephalus* among the fish seeds were the most abundant. The common penaeid prawn seeds were those of *Penaeus indicus*, *P. monodon*, *Metapenaeus dobsoni* and

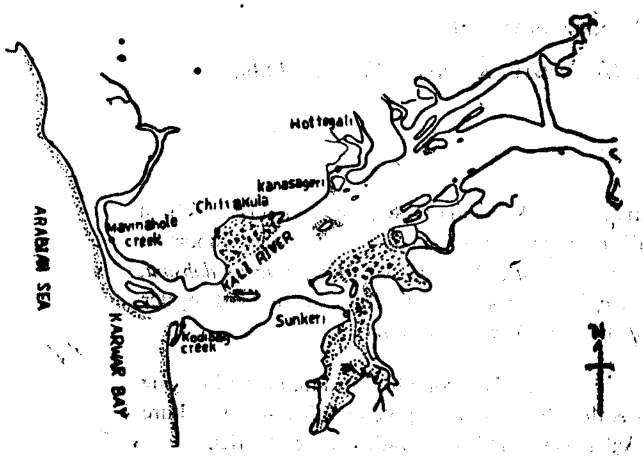

Fig. 1. Station locations in the Kali Estuary

M. monoceros. The prawn seeds exhibited considerable regional variations (Table 1) in that the regions of Sunkeri backwaters, Hottegali and Mavinahole creek recorded maximum abundance. However it was interesting to note that the seeds of *P. indicus* and *M. dobsoni* were dominant in the Mavinahole creek and Kodibag creek while the seeds of *P. monodon* and *M. monoceros* were most abundant in Hottegali Backwaters. The regions of Chittakule, Kanasageri and Kodibag creek showed moderate abundance of prawn seeds. Such regional variation was not evident in case of the seeds of *M. cephalus*, since they were found in abundance all along the Estuary. The other common fish seeds were those of *Etroplus suratensis* and *Scatophagus argus*.

The occurrence of seeds also showed marked seasonal variations (Table 2). The seeds of *P. indicus* and *M. dobsoni* made their appearance in November and October respectively, with steady increase to reach the maximum during December-February, followed by a pre-monsoon decline. The seeds of *P. monodon* appeared in November and persisted till January, rarely occurring in the pre-monsoon season. However, their appearance was again made out during July and August, when the monsoon was in full swing and salinity was low. It was also observed that the intensity of occurrence of *P. monodon* was more towards upstream. The seeds of *M. monoceros* started appearing in September, gradually increasing till February, followed by a gradual decline till the onset of monsoon. The seeds of *M. cephalus* were found to occur almost round the year, with maximum during November to January. The seeds of *E. suratensis* occurred during the period from September to December followed by a moderate abundance till March with negligible occurrence from April to August. The seeds of *S. argus* have a restricted occurrence found maximum only in February and March.

Besides the seeds of prawns and fishes, the Kali Estuary harboured dense spats of some molluscs *viz. Meretrix casta*, *M. meretrix*, *Crassostrea gryphoides* and *Perna viridis*. The estuary is particularly known for rich clam beds of *M. casta*, which are found in dense concentration in the region between the Sunkeri and Chittakula. The beds of *M. meretrix* were found at the extreme mouth of the estuary. The spat settlement of *M. casta* was found to extend mostly throughout the year, with a peak settlement period from July-September. The intensity of settlement decreased towards upstream. The edible oyster spats concentrated in the littoral regions of Mavinahole creek, Kodibag, Chittakula and Kanasageri. No prominent mussel beds could be located along Kali estuary, except near Sunkeri and towards the river mouth.

TABLE 1. *Prawn seed abundance (Catch-per net per hour) in different regions of the Kali Estuary*

Species	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
KODIBAG CREEK													
P. indicus ..	51	46	33	29	16	9	9	0	0	19	21	26	63
P. monodon ..	20	13	9	6	2	—	0	13	18	15	10	18	16
M. dobsoni ..	39	35	36	31	18	12	7	2	5	14	19	16	45
M. monoceros ..	16	20	18	20	15	6	3	0	2	6	12	29	21
MAVINAHOLE CREEK													
P. indicus ..	136	143	135	85	64	23	20	11	14	19	46	76	98
P. monodon ..	65	43	31	21	11	6	0	8	15	21	20	66	50
M. dobsoni ..	153	151	126	73	65	15	17	6	7	21	39	79	91
M. monoceros ..	132	136	113	76	45	20	16	5	9	7	33	24	103
CHITTAKULA													
P. indicus ..	60	57	39	26	21	14	8	3	5	28	36	51	69
P. monodon ..	20	18	19	12	6	0	0	0	0	7	6	8	13
M. dobsoni ..	52	61	43	31	28	16	11	7	3	37	32	59	64
M. monoceros ..	38	48	36	25	23	20	6	0	0	9	21	23	29
KANASAGERI													
P. indicus ..	70	68	51	43	31	18	3	2	4	12	14	35	65
P. monodon ..	31	36	16	2	2	0	8	6	11	2	0	0	10
M. dobsoni ..	85	53	69	59	64	43	17	8	0	6	18	43	76
M. Monoceros ..	51	43	21	8	3	0	0	0	5	16	18	15	35
SUNKERI													
P. indicus ..	125	115	95	90	72	38	13	5	8	12	36	58	97
P. monodon ..	176	59	47	26	10	0	0	22	35	33	16	21	63
M. dobsoni ..	136	135	110	96	63	41	11	7	13	18	35	50	91
M. monoceros ..	110	98	76	55	37	26	23	9	11	11	27	68	139
HOTTEGALI													
P. indicus ..	103	106	78	56	35	20	6	0	0	12	25	31	75
P. monodon ..	128	113	121	77	53	31	25	36	66	56	35	71	93
M. dobsoni ..	121	120	96	64	51	30	5	5	0	7	31	52	90
M. monoceros ..	143	140	135	98	68	42	16	9	10	27	21	79	105

TABLE 2. *Monthly variation of prawn and fish seeds in Kali Estuary*

Species	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Penaeus indicus ..	R	R	R	M	M	N	N	A	A	N	M	M	R
P. monodon ..	R	R	R	N	N	N	A	M	M	A	A	R	R
Metapenaeus dobsoni ..	R	R	R	R	M	M	N	A	A	N	M	M	R
M. monoceros ..	M	R	R	M	M	N	A	A	A	M	M	R	R
Mugil cephalus ..	M	R	R	R	M	M	M	M	M	N	N	M	R
Etroplus suratensis ..	R	M	M	M	N	N	A	A	N	M	R	R	R
Scatophagus argus ..	N	N	R	R	M	N	A	A	A	A	A	A	A

R = Rich ; M = Moderate ; N = Negligible ; A = Absent.

GENERAL REMARKS

The Uttara Kannada District of Karnataka is one of the potential coastal areas on the west coast of India for the development of coastal aquaculture. Besides, the four main estuarine systems, the District possesses culturable biotopes such as mangrove, tidal creeks and lowlying areas (Table 3). It is observed that the fish and shellfish seeds collected in the present study were mainly encountered in the mangrove areas which are not only productive, but also offer protective shelter for the seeds.

TABLE 3. *Extent of culturable areas in Uttara Kannada*

Taluk	Village	Seed source	Area in acres	Remarks
Karwar	Mavinahole creek	Kali estuary	5	Mangrove
	Chittakula	,,	3	,,
	Kanasageri	,,	1	,,
	Hottegali	,,	2	,,
	Sunkeri	,,	3	,,
	Chittakula	,,	76	Gazani land
	Kanasageri	,,	149	,,
	Sunkeri	,,	80	,,
	Kadawad	,,	400	,,
	Kinnar	,,	235	,,
	Siddar	,,	64	,,
	Hanakona	,,	100	,,
	Vailwad	,,	69	,,
	Kodibag	,,	4	Creek
	Chendiya	Chendiya Bay	40	Backwater
Kumta	Kadime	Aghanashini Estuary	87	Gazani land
	Gonehalli	,,	33	,,
	Nagarbail	,,	364	,,
	Madangeri	,,	246	,,
	Torke	,,	15	,,
	Hittaimakki	,,	289	,,
	Narayanpur	,,	28	,,
	Toregazani	,,	2	,,
	Hiregutti	,,	466	,,
	Morba	,,	270	,,
	Yannemudi	,,	146	,,
	Midlagazani	,,	364	,,
	Gokarn	,,	12	,,
	Arkeri	,,	11	,,
	Holegadde	,,	28	,,
	Horbag	,,	7	,,
	Harneer	,,	34	,,
	Bargi	,,	109	,,
	Paduwani	,,	266	,,
	Kelginsthal	,,	107	,,
	Savulkurve	,,	140	,,
	Kodkani	,,	62	,,
	Pattubali	,,	45	,,
	Tannirhond	,,	53	,,
	Mirjan	,,	32	,,
	Kalbag	,,	17	,,
	Kumta	,,	142	,,
	Honnalli	,,	23	,,

Prawn culture is being traditionally practiced in the lowlying areas in the Aghanashini estuarine region in Kumta Taluk. However, this system has not been extended to the other areas such as the Kali, Sharavathi and Gangavali Estuaries which offer wide scope for expanding the brackishwater fish culture activities. Besides the expansion of fish and prawn culture fisheries, there is good scope for developing the molluscan culture, particularly for the culture of the clam, *M. casta* as revealed by the seed resource available in different estuaries.

In order to accelerate the process of development of aquaculture in the District, it is suggested that immediate steps be taken to undertake a survey of the coastal waters of the district to locate suitable sites for the development of farms and to assess the availability and abundance of seeds of cultivable species. It is also essential that the culture sites are given to the farmers on a long term lease basis with adequate financial encouragement for the development of the fields. Demonstrations of viable technologies developed in the field of coastal aquaculture/mariculture may also be arranged for the wide propagation of this technologies among the fishermen and fish farmers.

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NOTES

IMPROVED PRAWN PRODUCTION THROUGH SELECTIVE STOCKING

ABSTRACT

Prawn farming demonstration conducted in the farmers' pond around Cochin with the technical assistance of the Marine Products Export Development Authority, to propagate scientific prawn farming were briefly outlined. Two of the culture operations in ponds, located at Pandarachira and Vallarpadom, having an area of 0.22 ha and 1.16 ha respectively, were reported in detail along with the economics. In a 0.22 ha pond, mixed culture of *Penaeus indicus* and *P. monodon* was undertaken for a period of 90 days during January-April 1979 and the net production obtained was 112.5 kg. Monoculture of *P. indicus* was conducted in a 1.16 ha pond for 65 days from March to May 1979 and a total of 560 kg of prawns were harvested. The production rates of 511 kg/ha/90 days and 483 kg/ha/65 days obtained in these operation are highly encouraging and indicative of commercial viability. The strategy for converting the traditional prawn filtration fields into selective culture farms in Cochin is discussed in the light of the results obtained.

PRAWN production through culture have gained momentum in the wake of greater consumer demand in the international market, and due to the unsteady landings from capture fisheries. Appreciable advance has been made in research leading to the development of culture techniques of penaeid prawns in the country (Jhingran, 1977; Swaminathan, 1978; Alikunhi, 1978; Silas, 1978). Procedure of selective stocking developed by various Research Instituitions in the country have not yet been fully utilised on commercial scale. In this context the Marine Products Export Development Authority has taken up a scheme to promote brackishwater prawn farming in the country. Field demonstrations were arranged under this programme to prove the commercial viability. The successful prawn farming demonstrations conducted by MPEDA in the farmers' ponds around Cochin during 1978-79 have brought home the advantages of scientific prawn farming among the traditional prawn farmers. Two of such operations, in ponds located at Pandarachira and Vallarpadom in the Vembanad Backwater having an area of 0.22 ha and 1.16 ha respectively, are reported along with their economics.

The authors are grateful to Sri. S. Gopalan, IAS, former Chairman, Dr. T. A. Mammen former Director, Sri. R. C. Chaudhuri, IAS, Chairman and Dr. M. Sakthivel, Joint Director of the Marine Products Export Development Authority, Cochin for their interest and encouragement given in conducting the studies.

Materials and Methods

In a 0.22 ha pond located at Pandarachira, about 15 kms south of Ernakulam, mixed culture of *Penaeus monodon* and *P. indicus* was adopted and in a 1.16 ha pond, located at the Vallarpadom Island within the Cochin Backwater, only *P. indicus* was stocked. Both these fields are surrounded by paddy-cum-prawn filtration field that receive water from Vembanad Lake.

Postlarvae and juveniles of *P. indicus* collected from the Cochin Backwater using small drag nets were temporarily stored in plastic pools, kept at the MPEDA field camp at Puduvypu, were transported to the farm under oxygen packing. *P. monodon* seed procured and transported from Kovelong in Tamil Nadu and Kakinada in Andhra Pradesh were used in mixed culture demonstration. The ponds were treated with Mahwa oil cake @ 200 ppm to clear off all the unwanted fishes and prawns. The pond water was replenished whenever necessary with fresh tide water through inlets guarded with velon screens. Stocking was done at Pandarachira in the first week of January 1979 at the rate 52,000/ha with *P. indicus* and *P. monodon* in the ratio of 4 : 1 and during the last week of March 1979 with *P. indicus* at the rate of 70,000/ha in the Vallarpadom pond.

Monthly samples were taken by cast netting to assess growth and survival. The individual live prawns were replaced into the ponds after measurements. The ponds were harvested by repeated netting and draining during the first week of April at Pandarachira and during the last week of May at Vallarpadom. Record of water quality like pH, salinity and temperature was maintained throughout the culture period. No supplementary feed was given to the stock during the experiments.

In the mixed culture operation of *P. indicus* and *P. monodon* practised in the pond at Pandarachira, early juveniles of the size 21-50 mm were stocked and reared for 90 days, from January to April 1979. The water temperature ranged from 27°C-31°C and salinity from 19‰-25‰. The pH was in the range of 7.8-8.4. The frequency distribution of size groups of *P. monodon* and *P. indicus* at 10 mm intervals on sampling dates during the culture period January-April 1979 are presented in the Table 1.

From the progression of distribution of size groups it can be seen that the prawns exhibited rapid growth under culture conditions. Growth of *P. monodon* was faster than that of *P. indicus*, the former grown from the size range of 21-50 mm to 101-180 mm while the latter has grown from the size range of 21-40 mm to 71-130 mm by 4-4-79. The average size of *P. monodon* was 143.06 mm/22.9 gm and of *P. indicus* was 112.15 mm/11.25 gm at the time of harvest. Net production at the rate 512.5 kg/ha/90 days was obtained from this culture. Survival rate calculated at the harvest was 88.71% and 73.24% for *P. indicus* and *P. monodon* respectively. Average unit value realised for the whole white and tiger prawns were Rs. 24.10/kg and Rs. 43.46/kg respectively. The gross return of Rs. 3,176 from this field works out @ Rs. 14,436/ha/90 days.

In the monoculture operation practised at Vallarpadom pond juveniles of 21-50 mm were stocked and reared for 65 days during March-May 1979. Water temperature in the pond ranged from 30°C-38°C, salinity ranged from 30‰ to 35‰ and pH 8.0-8.8. The frequency distribution of size groups of prawns at 10 mm interval during the culture period from March to May 1979 is presented in Table 2. The culture could not be extended beyond last week of May 1979 as sufficient depth of water was not available. Exchange of water was also not possible due to the draining of nearby field for paddy cultivation. As the shallow water was getting heated up the prawns were showing signs of distress. At the time of harvest the prawns were of the average size. 108.5 mm/10.0g. However, the timely harvest could save the crop and the survival rate recorded was 75.86%. The production.

TABLE 1. *Length frequency of* P. monodon *and* P. indicus *at Pandarachira*

Size groups TL. in mm	Percentage frequency of size groups on dates 4-1-79 P.m	4-1-79 P.i	1-2-79 P.m	1-2-79 P.i	3-3-79 P.m	3-3-79 P.i	4-4-79 (Harvest) P.m	4-4-79 (Harvest) P.i
21-30	20.18	49.62	—	—	—	—	—	—
31-40	18.22	50.38	—	—	—	—	—	—
41-50	61.60	—	—	2.20	—	—	—	—
51-60	—	—	20.24	10.15	—	—	—	—
61-70	—	—	22.33	10.36	—	11.82	—	—
71-80	—	—	11.05	8.00	—	11.14	—	9.31
81-90	—	—	9.56	15.47	19.69	10.36	—	10.00
91-100	—	—	8.12	23.20	22.75	13.80	—	12.99
101-110	—	—	7.86	30.62	10.92	25.47	20.33	14.30
111-120	—	—	11.82	—	9.62	27.36	25.31	24.12
121-130	—	—	9.56	—	8.25	—	7.05	29.26
131-140	—	—	—	—	6.26	—	7.88	—
141-150	—	—	—	—	12.16	—	8.30	—
151-160	—	—	—	—	10.35	—	10.37	—
161-170	—	—	—	—	—	—	12.45	—
171-180	—	—	—	—	—	—	8.30	—
Sample No.	46	54	86	112	67	85	240	296
Av. wt (g)	0.42	0.25	8.5	6.75	13.6	9.32	22.9	11.25
Av. L. (mm)	44.14	35.04	87.95	91.65	118.31	98.71	143.06	112.15

P.m = *P. monodon* P.i = *P. indicus*

TABLE 2. *Length frequency of* P. indicus *at Vallarpadom*

Size groups TL. in mm	Percentage frequency of size groups on dates 26-3-79	4-5-79	30-5-79 (Harvest)
21-30	26.52	—	—
31-40	48.18	—	—
41-50	35.30	—	—
51-60	—	—	—
61-70	—	—	—
71-80	—	6.82	—
81-90	—	27.27	—
91-100	—	31.82	18.12
101-110	—	31.82	69.19
111-120	—	2.27	11.89
121-130	—		
No. of Sample	86	44	185
Av. wt (g)	0.35	6.5	10.0
Av. L. (mm)	44.89	99.55	108.6

obtained was @ 483 kg/ha/65 days. Average Unit value realised was Rs.18.0/kg. The total realisation was Rs. 10,080 from the pond that amounts to Rs. 8,690/ha/65 days culture.

Discussion

The main objective of the culture operation given in this paper was to show the commercial viability of prawn farming through selective culture. Similar studies were reported from Cochin area by Mammen *et al.* (1978) Gopalan *et al.* (1978) have reported certain improved prawn culture procedure in prawn filtration fields at Vypin Island in Cochin area. The fields where the present observations made, were not used for traditional prawn filtration as the rate of ingression of prawn seed were observed to be very negligible. Slow growing species like *Metapenaeus dobsoni* only were noticed from the vicinity of these fields.

The Annual rate of production from successful filtration fields has been estimated at 1079 kg/ha. (Menon, 1954) ; 1184/kg/ha, (Gopinath, 1956) ; 514 kg/ha. (George, *et al.*, 1968); 903.3 kg/ha (George, 1974); 637/kg/ha (Gopalan *et al.*, 1978). The harvest mostly comprises prawns like *M. dobsoni* having low value realisation.

The production rates recorded from improved method of paddy field shrimp culture from the Vypin Island reported by Gopalan *et al.* (1978) were in the range of 784.92 kg-965.04 kg/ha. In the above yield smaller prawns formed about 27-48% with the result that the unit value realisation per kg of prawns reported was only Rs. 8.56 in 75-76, Rs. 9.77 in 76-77 and Rs. 9.35 in 77-78. From the selective culture operation presented in this paper the total income works out to be Rs. 14,436/ha for 90 days from a 0.22 ha pond; and Rs. 9,418.5/ha for 65 days culture from 1.16 ha pond. The higher unit value realisation reported in this paper is due to the selective stocking practice adopted where only quality prawns were reared. The comparatively higher realisation from the 0.22 ha pond was due to the presence of *P. monodon* that formed 21.33% of the total harvest.

Even though the selective culture can produce quality prawns of higher unit value it may not be possible to put this into practice immediately in all the existing prawn filtration units, because of the shortage of required prawn seed at the present level of procurement (Rao, 1978). The natural abundance of prawn seed is limited to a few months of the year (Verghese *et al.*, 1979) and hence it is not possible to relay on natural source when more than one crop is contemplated in larger areas. However, if each filtration apart about 10% of the area for selective stocking with proper management, it may be possible to stock with the juveniles of fast growing species retrieved from the filtration net used to catch prawns in the traditional methods. This valuable prawn seed is being caught and sold at present along with other smaller varities of prawns. About 5117 ha area is being utilised for prawn filtration in Kerala (Rao, 1978). Nearly 500 ha from this can easily be converted into selective stocking ponds to obtain a total production of 250 tonnes per year at a conservative estimate of 500 kg/ha/crop of 3-4 month duration. With the establishment of commercial hatchery, to produce postlarvae of *Penaeus* indicus, *P. monodon* and other fast growing prawns, two crops can be raised in the improved culture field and the production can be doubled. The MPEDA's programme of technical assistance to prawn farmers aims at meeting this objective and to bring in more and more area into scientific prawn farming in a phased manner.

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PRAWN CULTURE IN THE PADDY FIELDS OF UTTARA KANNADA DISTRICT, KARNATAKA

Abstract

The culture of prawns in the low lying paddy fields adjacent to backwaters and estuaries is the most common and traditional method adopted in many parts of India. However, this practice, of late, has been followed in some places of Uttara Kannada.

The present paper reports on the extent and nature of paddy-prawn culture as practiced in Karwar, Kumta and Honnavar. The important species that are cultured are *Penaeus indicus, P. monodon, Metapenaeus dobsoni* and *M. monoceros*. The production rates are found to vary from one farm to the other. Details of the lay out of the farms, stocking, nutrition, suitability of the species, and merits and demerits of each farm are presented and discussed.

In Uttara Kannada District of Karnataka State, prawns are cultivated following the traditional method of 'holding and trapping the juveniles brought in by the incoming tidal currents in paddy fields lying adjacent to the main estuarine systems *viz.*, Kali, Aghanashini and Sharavathi, in the coastal taluks of Karwar, Kumta and Honnavar respectively. The paddy fields which are used alternatively for prawn culture are locally called as 'Gazani' lands. The paddy cultivation in these fields begins at

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The present paper reports on the extent and nature of paddy-prawn culture as practiced in Karwar, Kumta and Honnavar. The important species that are cultured are ***Penaeus indicus, P. monodon***, *Metapenaeus dobsoni* and *M. monoceros*. The production rates are found to vary from one farm to the other. Details of the lay out of the farms, stocking, nutrition, suitability of the species, and merits and demerits of each farm are presented and discussed.

IN Uttara Kannada District of Karnataka State, prawns are cultivated following the traditional method of 'holding and trapping the juveniles brought in by the incoming tidal currents in paddy fields lying adjacent to the main estuarine systems *viz*., Kali, Aghanashini and Sharavathi, in the coastal taluks of Karwar, Kumta and Honnavar respectively. The paddy fields which are used alternatively for prawn culture are locally called as 'Gazani' lands. The paddy cultivation in these fields begins at the onset of monsoon when the fields get desalinated due to heavy freshwater influx and lasts upto the end of September or beginning of October. After a brief exposure of fields to tidal influence, preparations for prawn culture are made by clearing of the bottom, construction of bunds and fixing up of sluice gates. Stocking is done at every high tide when the seed enriched estuarine water is impounded in the fields. The major seeds of prawn that enter into the field belong to *Penaeus indicus*, *P. monodon*, *Metapenaeus dobsoni* and *M. monoceros*. These are allowed to grow for a period of 4-6 months before harvest, which begins generally at the end of February or beginning of March. The harvesting, which is a dusk to dawn process, is usually carried out during the full and new moon periods, using a bag net (conical type) which is fixed towards the outer side of the sluice and letting the water to flow through. During final harvesting the entire water in the farm is drained and the prawns that are left behind are collected with the help of bag and scoop nets. The prawns are then collected in the baskets and are graded depending on the size *viz.* Grade I : *P. monodon* and *P. indicus* of 10 cm and above; Grade II: *P. indicus* of 8 cm size and above ; Grade III : *P. indicus* of 4-6 cm (locally called 'Temil'); and Grade IV: *Metapenaeus* sp. The graded prawns are then spread in insulated boxes which are transported to the nearby freezing plants. The yield varies from farm to farm depending on its location. However, the present rate of production on an average is about 200 Kg/ha. *Therapon jarbua* and Gobid fishes make their way into the farm and cause relative reduction in the average production. Besides prawn, fishes such as *Mugil cephalus*, *Etroplus suratensis* and *Teuthis vermiculatas* which are frequently encountered in the farm, are also fished and sold locally forming an additional sources of income.

The culture practise followed being simple, cost of operation is kept to the minimum. Some farmers use cowdung for fertilising the field and rice bran as feed particularly during the initial stage of the operation. Some culturists also practise the actual collection of seeds from estuary employing trained fishermen. Such stocking is mostly restricted to *P. monodon* and *P. indicus*.

In order to asses the economics of the culture operation, a case steady was undertaken during 1978-79 at an experimental prawn farm at Hottegali with an area of 15 acres adjoining the Kali Estuary, belonging to the Fisheries Department, Government of Karnataka. The total expenditure on lease (Rs. 2,700), manual labour (Rs. 500) and maintenance of the field (Rs. 200) was 3400. A total yield of 31 kg of *P. monodon*, 189 kg of *P. indicus* and 273 kg of *M. dobsoni* was obtained realising a value of Rs. 7,102. The net profit from the operation was Rs. 3,702.

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DEVELOPMENT OF BRACKISHWATER PRAWN FARMING IN TAMIL NADU

ABSTRACT

Tamil Nadu offers a rich potential for development of brackishwater prawn farming. The brackishwater resources of the state have been estimated at about 2 lakh hectares and of this about 27,000 hectares can readily be subjected to prawn farming at reasonable cost. Till 1977, the vast cultivable brackishwater resources remained unutilised for aquaculture purposes. The demonstrations on prawn farming held by the State Fisheries Department during 1977 and thereafter have attracted a number of private entrepreneurs towards this new field. About seventy-five prawn farms have already come up on the private sector and nearly 300 farms are under construction in the various maritime districts. The favourable conditions that have helped the development of prawn farming in the State and the various problems faced in keeping up the pace of development are discussed.

TAMIL NADU offers a rich potential for development of brackishwater prawn farming. The brackishwater area of the state have been estimated at about 0.2 million hectare of this about 27,000 hectares could immediately be developed to carry out prawn farming. Besides, the State also possesses suitable species of fast growing prawns such as *Penaeus indicus*, *P. monodon* and *P. semisulcatus* along its coastal waters.

Till 1977, the vast cultivable brackishwater resources remained unutilised for aquaculture purposes. The demonstrations on prawn farming conducted by the Fisheries Department during 1977 and in subsequent years have attracted several private entrepreneurs into this field. About seventy-five prawn farms have already come up in the private sector and nearly 300 farms are being constructed in the various maritime Districts of the State. Table 1 gives the District-wise break-up of the private prawn farms constructed in Tamil Nadu during 1978 and 1979.

Most of these farms are owned by marginal farmers (possessing less than 1 hectare land) who have either constructed the ponds in their own lands or in the lands given to them on long lease by the State Government, Local Bodies, and Temple Trusts. Some of them have converted fallow fields and abandoned salt pans into prawn farms. While the size of the individual ponds varies from 0.3 to 2.2 hectare, there are also a few farms as large as 10.5 hectare in extent constructed and owned by certain Industrialists. In some Districts, especially in Thanjavur and Chingleput, institutional finance has been made available for the construction of the ponds and the operational expenses. The production of prawns in these farms was found to vary from 200-400 kg/ha/crop and the income from Rs. 3,000 to Rs. 10,500.

TABLE 1. *District-wise break-up of the private prawn farms constructed in Tamil Nadu*

District	Number of farms	Approximate water spread area in hectare
Chingleput	12	29.0
South Arcot	5	5.0
Thanjavur	50	52.0
Pudukottai	1	1.3
Tirunelveli	3	5.0
Kanyakumari	2	2.5

A number of schemes have been proposed by the State Fisheries Department for the accelerated development of brackishwater prawn farming in Tamil Nadu. Ten demonstration farms, each with one rearing

Pond of 1 ha area and 10 nurseries of 0.1 hectare each would be constructed in the coastal districts for extending the technology of prawn farming to the fishermen. These farms will also hold stock of seeds of prawns in nurseries and supply them to the prawn farmers. As fishermen cannot get requisite capital for the construction of ponds and farming operations, Co-operatives are being organised to help them to start prawn farming. Government lands are proposed to be given to the Co-operatives on long lease. It is also proposed to impart training on prawn farming to about 600 rural youths and fishermen during 1980. The survey for identifying suitable sites for construction of farms, and seed grounds is intensified. The distribution pattern and abundance of prawn seed resources in some of the important brackishwater bodies such as Pulicat Lake and Ennore, Kovalong and Killai Backwaters, Adyar, Markannam, Vellar and Coleroon Estuaries and Muthupet Swamp have been studied. The surveys carried out have revealed that the seeds of *P. indicus* and *P. semisulcatus* abound respectively in the estuaries of the northern and southern region of the State.

While the above R & D efforts envisage to quicken the brackishwater prawn farming, inadequate facilities for Extension, scarce flow of finance and non-availability of seeds of desired species of prawns are found to be the main constraints encountered in the frontiers of progress in the field.

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TRANSPORT OF PRAWN SEED

Abstract

Transport of *Penaeus indicus*, *P. monodon* and *P. semisulcatus* postlarvae (10-20 mm) was done under ordinary and oxygen packed conditions in transparent polythene bags of 20 litre capacity with folds at the bottom. The number of seeds packed was 200 and 500 keeping the volume of water and duration of transport constant. Double polythene bags were used as a safeguard measure against rostrum puncturing. 100% survival was noted when 200 seeds were transported, the duration being 12 hours. 3% mortality was noted when 250 seeds were transported. Mortality was 10% when 500 seeds were transported. Mortality was 50% when 200 seeds were transported without oxygen in 12 hours. An optimum of 500 postlarvae can be transported under oxygen packing in polythene bags profitably.

Monoculture of penaeid prawns especially *Penaeus indicus* and *Penaeus monodon* in dug out ponds along the coastal belt is gaining momentum in Tamil Nadu. Such selective culture operations require large number of quality prawn seeds. In the absence of prawn hatcheries, the seeds have to be collected from brackishwater lakes, lagoons and swamps. The postlarvae of *Penaeus indicus* are available round the year in varying abundance at Pulicat Village and other areas of Tamil Nadu, with peak periods of availability during January to March and June to September. Postlarvae of *Penaeus monodon* are available during October to January and March to April. Peak period of availability for *Penaeus semisulcatus* is from October to January. Seeds obtained

TRANSPORT OF PRAWN SEED

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The authors thank Mr. Ramachandra Menon and Mr. A. Sreenivasan for their suggestions, interest and encouragement in preparing this paper.

Material and Methods

The postlarvae of *Penaeus indicus* and *Penaeus semisulcatus* were collected from Lake Pulicat in the shallow water by dragging a velon screen strip of 6 m × 1.5 m size. *Penaeus monodon* were collected from Porto Novo and Kovalam Backwaters. A mixed size group of 15-20 mm seeds were collected by dragging (200-1000 seeds/net/hour) the velon screen strip. The seeds were identified based on the characters described by Rao and Gopalakrishnan (1968). After collection, they were segregated and conditioned for about 2 hours in the plastic basins in water from the lake. After conditioning, the seeds were packed in gusseted type of polythene bags with 5 litres of filtered lake water and oxygenated for about five minutes. Then the bag was inflated above the water level with oxygen and tied tightly. The dissolved oxygen level and other chemical parameters of the medium determined before tying the polythene bag were as follows.

Temperature	27.2°C
Salinity	24.5‰
Dissolved Oxygen	6.8-7.0 ppm

Results and Discussion

The results of the experiments are presented in the Table 1. An analysis of

TABLE 1. *Mortality rates of postlarvae under oxygen packing at varying densities and duration* (*Size of seed:* 10-20 *mm*)

Number of seeds/5 L	6 Hours			12 Hours			18 Hours			24 Hours		
	P.i.	*P.m.*	*P.s.*	*P.i.*	*P.s.*	*P.m.*	*P.i.*	*P.m.*	*P.s.*	*P.i.*	*P.m.*	*P.s.*
200 ..	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	2	3
250 ..	Nil	Nil	Nil	3	2	Nil	6	4	5	9	6	7
300 ..	Nil	Nil	Nil	4	3	3.5	7	5	7	10	7	8
350 ..	Nil	Nil	Nil	6	4	4	9	6	8	12	8	10
400 ..	2	1	1.5	7	6	5	11	8	10	16	9	13
450 ..	3	2	2	9	7	8	13	9	11	17	11	15
500 ..	5	3	4	10	8	9	14	11	12	20	13	17

P.i. — *Penaeus indicus* *P.m.* — *Penaeus monodon* *P.s.* — *Penaeus semisulcatus* the results indicate higher survival percentage of *Penaeus monodon* followed by *Penaeus semisulcatus* and lesser survival percentage of *Penaeus indicus* under identical conditions.

Survival was 100% when 200 seeds were transported, the duration being 12 hours. 10% mortality was observed when 500 seeds were transported.

Thus, it is evident from the Table that transport of 200 seeds of 15-20 mm could be effected profitably with no mortality in a period of 12 hours and 500 with 10% mortality. It is further evident that 200 seeds could be safely carried over a duration of 18 hours with no mortality. De (1977) has transported 200 seeds/L in a period of 12 hours with a mortality of 15.2%. To minimise mortality over prolonged duration of 24 hours, 350 seeds could be safely carried with a maximum mortality of 12%. If 500 seeds are required to be carried over in 24 hours duration, mortality would be upto 20%.

The dissolved oxygen level of the medium varied between 6.8 and 7.0 ppm at the time of packing. Dissolved oxygen of the medium was 0.9 ppm after 6 hours duration and 0.6-0.9 ppm after 12 hours duration. It was observed that putrefaction of the dead prawns induced depletion of dissolved oxygen at a faster rate beyond 12 hours. De and Subrhamanyam (1975) stated that depletion of dissolved oxygen was not the main cause for high mortality during transport which is in accordance with our findings. In addition to the low dissolved oxygen of the medium and other factors, injury at the time of collection and handling could possibly be the cause for higher rate of mortality in the case of *Penaeus indicus*. *Penaeus monodon* and *Penaeus semisulcatus* could stand the handling process better. The other possible reasons for mortality could be starvation and cannibalism. De and Subrhamanyam (1975) observed that starvation and handling of seeds could be the possible reasons for higher rate of mortality. *Penaeus monodon* and *Penaeus semisulcatus* packs showed no remnants of the dead prawns in some of the consignments and hence the dead ones are deemed to have been eaten up.

Survival percentage was higher with lesser concentrations as observed by Mammen *et al.* (1978) in respect of *Penaeus monodon* which supports our findings in respect of the three species mentioned. Mohanty and Patra (1972) also observed 100% survival while transporting 100 seeds of *Penaues indicus* in a period of 9 hours the size being 12-18 mm.

Postlarvae of *Penaeus monodon*, *Penaeus semisulcatus* and *Penaeus indicus* could thus profitably and dependably be transported over 12-18 hours duration under oxygen packing.

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ON THE GROWTH OF *PENAEUS INDICUS* EXPERIMENTED IN CAGES AT DIFFERENT DENSITIES IN A SELECTED NURSERY GROUND

ABSTRACT

Effect of different densities on the growth of *Penaeus indicus* was studied in a highly productive nursery ground located at Ramanthuruth Island (lat. 9°58′50″N, long. 76°15′40″E) using cages. Eight cages of the same size were placed with prawns in sets of 5, 10, 20, and 40 of the nearest size range (between 30 and 35 mm) and their growth was recorded once in every fortnight for six months. The average growth in length in the first month in different densities were 28.1, 22.00, 18.6 and 10.4 mm respectively which progressively decreased in subsequent months. The relevance of the present experiment in the culture of *P. indicus* is discussed.

A KNOWLEDGE of the growth pattern of the commercially important species of prawn and the factors that govern their growth rate are essential for their successful cultivation. Fairly large number of literature on the various aspects of the biology and fishery of the common penaeid prawns of India are available although information on their growth is much restricted and is based mostly on length frequency studies. Most of the penaeid prawns have extended spawning period which makes the growth studies on length frequency more difficult and less reliable. Although *Penaeus indicus* is a commercially important species, highly preferred for its size, information on the dynamics of growth is still not extensive. This information is particularly relevant in the present context of large scale efforts to culture this species in the Cochin Backwater. The present study was therefore taken up to collect more information on the growth pattern of the species in different densities.

The authors are grateful to Dr. S. Z. Qasim, Director, National Institute of Oceanography, Goa for his interest and constant encouragement.

Materials and Methods

The experiment was conducted in January-July, 1979, using cages in a fairly large and highly productive tidal pond having an area of nearly thirty acres located in Ramanthuruth Island (lat. 9°58′50″N, long. 76°15′40″E) near the Cochin Horbour entrance. The study formed part of a project to understand optimum environmental conditions for large-scale culture of prawns. The data collected on the physico-chemical and biological aspects of the environment in the area selected for this study are being published separately.

Juveniles of *P. indicus* were collected using small meshed cast net and kept in cages for a few days for getting acclimatised to the cages. They were then measured from the base of the rostrum to the tip of the telson and the smallest prawns of the same size available in sufficient numbers were selected and transferred to the cages immersed in the pond at a depth of about 1 m at low tide. The experiment was conducted in replicates in densities of 5, 10, 20 and 40. The initial size of the experimental prawns ranged from 30.0 to 35.4 mm. Length measurements were taken once in every fortnight. In order to maintain the same density, cages were checked twice a week to replace any loss due to escape or mortality, taking care to see that they were of the same size as those in the cages at the time of replacement.

The cages were of the size 50 × 50 × 30 cm (Fig. 1). A frame was first made using a 1.27 cm diameter PVC pipe and was covered

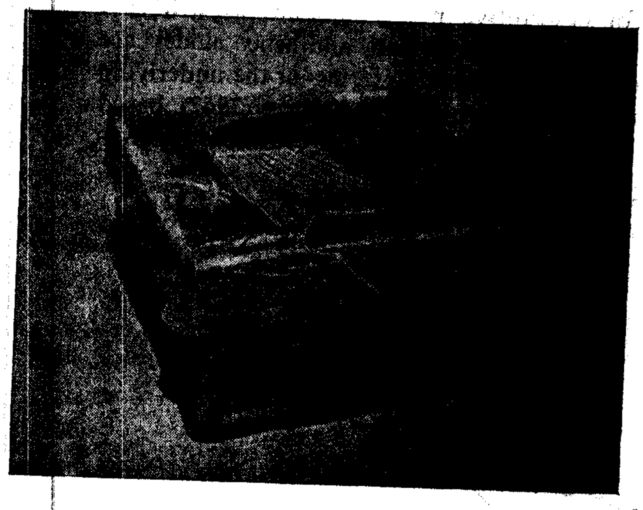

Fig. 1. Cage used for the experiment.

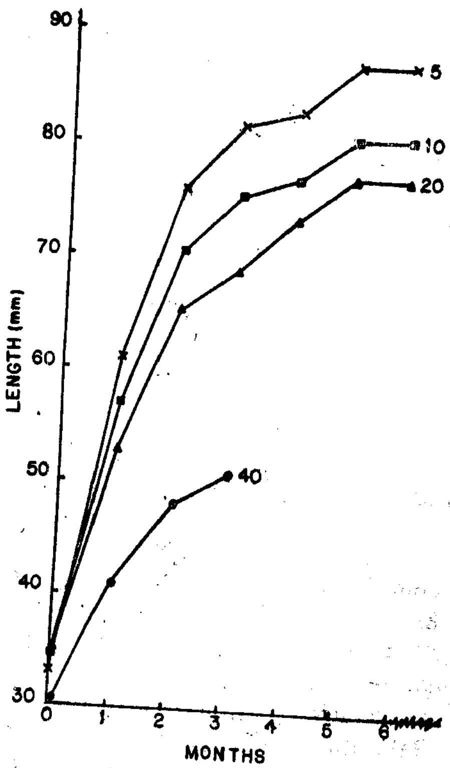

Fig. 2. Growth curve of *P. indicus* at different densities.

with a wire meshed net (mesh size 3 mm) except at the top where nylon nettings of nearly the same mesh size was used to permit closing and opening of the cage (Fig. 1). The wire was coated thrice with M. Seal Anticorosive Epoxy compound to prevent rusting.

Results and Discussion

The growth curve of *P. indicus* in different densities is given in Fig. 2 and the Ford-Walford plot in Fig. 3. The Bertalanffy growth equation

$$l_t = l_\infty [1 - e^{-k(t-t_o)}] \qquad (1)$$

where

l_t = length at time t

l_∞ = asymptotic length

k = rate of attaining the asymptotic length

and t_0 = the age at which the length is zero had the growth been throughout according to the Von Bertalanffy growth equation

is fitted to the growth data with the constraint that $t_0 = 0$ since the actual age of the prawn at the start of the experiment is not known. The fitted equations to the data in order of density are

$$l_t = 87.7 (1 - e^{-0.834t})$$
$$l_t = 80.8 (1 - e^{-0.718t})$$
$$l_t = 78.9 (1 - e^{-0.555t}) \text{ and}$$
$$l_t = 55.6 (1 - e^{-0.559t})$$

As expected from the Walford plot (Fig. 3) all the growth curves have been described by the Bertalanffy equation reasonably well. Banerji and George (1967) also found that the Bertalanffy equation gave a good fit to modal size groups of *Metapenaeus dobsoni*. However, the value of k in the present study is much higher than their estimate and may be largely due to the sharp decline in the growth with time under the experimental conditions.

Asymptotic length, l_∞ and k were also found to vary with density. Baverton and Holt (1957) have pointed out that if the Bertalanffy equation truly represents the growth pattern, changes in growth due to changes in density

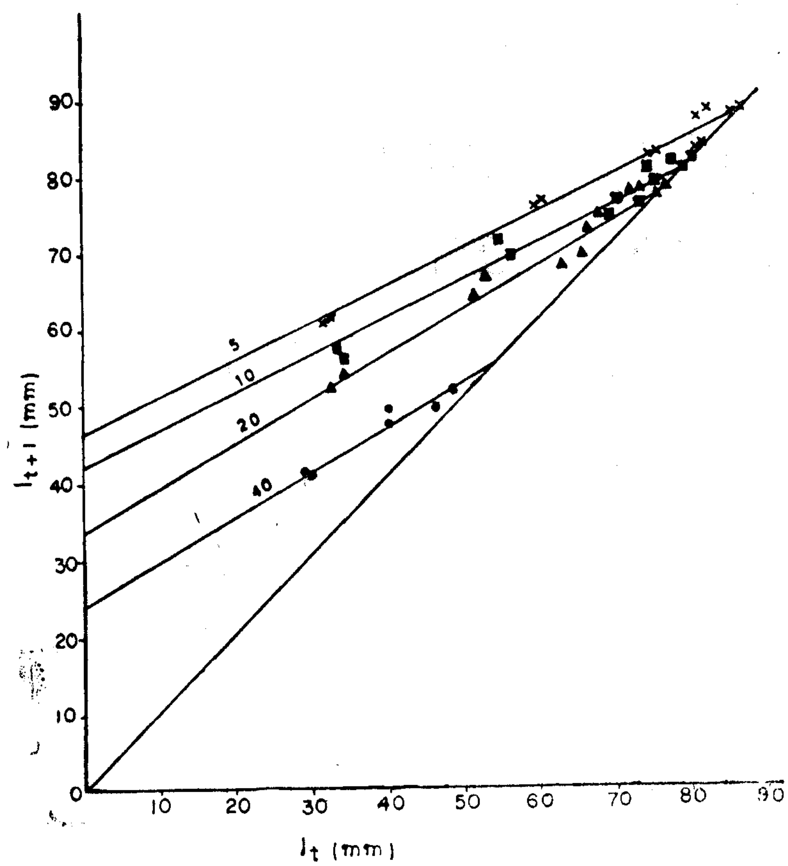

Fig. 3. Ford-Walford plots of the growth in length of *P. indicus* at densities 5, 10, 20 and 40.

will largely be brought about by changes in the asymptotic size while k remains more or less constant except when temperature is also altered. But the physiological basis of the Von Bertalanffy equation has been questioned by Richards (1959), Taylor (1962), Ricker (1958, 1960), Paloheimo and Dickie (1965) and others. Dickie (1971) points out that most of the growth equations are useful only for descriptive purposes since growth is a highly complex process and hence models are often not realistic in terms of the underlying mechanisms involved. Kurata (1962) based on an extensive study of the crustacean growth has concluded that their growth occurs in two or three phases. Unpublished data on the growth under different levels of feeding (Sreekumaran *et al.* in preparation) indicate that the Bertalanffy equation cannot describe season. Balasubramanian *et al.* (1979) have pointed out that the penaeid prawns have a voracious feeding capacity which may be taken advantage of in augmenting their the early growth of both *P. indicus* and *Metapenaeus dobsoni* in the size range 32.0-101.2 mm and 24.5-70.0 mm respectively since the growth increment did not show any decreasing trend within this size range. Further studies are therefore needed to throw more light on the dynamics of the growth of prawn.

The growth was highly sensitive to change in density and showed a sharp decline with time (Table 1, Fig. 2). Even in the cage with minimum density, the growth was very much retarded with increase in the size of prawn. The growth recorded in all cages in the first month except those having the highest density of prawns was quite high when compared to published results on *P. indicus* in Cochin Backwater as reviewed by George (1975). He recorded a growth of 14.9 mm/month and pointed out that the earlier estimates were much lower. The highest growth recorded in the present study was 28.1 mm/month. George (1974) observed specimens as large as 165 mm which suggest a fast growth rate at least in certain areas of the backwater. Suseelan (1975 a, 1975 b) has recorded growth rate higher than 30 mm per month in Manakkudy Estuary near Cape Comorin with maximum growth rate as high as 37.5 mm per month. Sreekumaran *et al.* (Per. comm.) have shown that prawns could maintain an uniformly high growth rate under favourable conditions for a few months. These evidences suggest the possibility of rearing *P. indicus* to a large size within a growth. Therefore the effect of physiological aging alone appears to be the main constraint that puts a limit to the maximum size that can be obtained by such means.

Although much effort has been taken to conduct the present study as carefully as possible and has yielded useful and reliable information on the growth of *P. indicus*, it has a few limitations which however do not seem to have seriously affected the data. For example, loss due to mortality or possible escape through openings in the top nylon net portion of the cage and even in the wire meshes occasionally caused by the crabs were replaced only twice a week in order to maintain the same density of prawns (Table 2). Such instances were, however, not frequent and only on two occasions the number of prawns replaced in one cage having the highest density exceeded twenty. Whenever a hole was noticed, which except on 2 or 3 occasions were quite small, it was

TABLE 1. *Average monthly growth (mm) of* P. indicus *in different densities*

Density	Average initial length	Months					
		1	2	3	4	5	6
5	33.0	28.1	15.0	5.5	1.0	4.5	1.0
10	34.7	22.0	13.7	4.9	1.6	3.9	1.0
20	34.6	18.6	12.2	3.4	4.7	3.8	1.0
40	30.5	10.3	7.3	2.5	—	—	—

TABLE 2. *Record of prawns introduced during the course of the experiment to replace loss due to escape/mortality*

Date of replacement	Density							
	5	5	10	10	20	20	40	40
9-2-1979	—	—	—	2	13	5	4	—
21-2-1979	—	—	—	—	—	—	—	30
6-3-1979	—	—	1	—	1	—	—	—
14-3-1979	—	—	—	—	—	—	5	—
23-3-1979	—	—	—	—	—	—	—	23
12-4-1979	1	—	2	1	3	3	—	—
27-4-1979	1	—	3	2	5	7	—	—
29-5-1979	—	—	—	—	4	—	—	—

immediately repaired or the cage replaced. In addition to biweekly visits by the scientists, a reliable person was also engaged to check the cages daily and change their position to ensure fresh supply of food as often as possible.

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NURSERY REARING OF POSTLARVAE OF TWO COMMERCIALLY IMPORTANT PENAEID PRAWNS IN NYLON CAGES

ABSTRACT

As efficient nursery rearing of prawn postlarvae is an important step for successful prawn farming. Attempts have been made at the Tamil Nadu Mariculture Research Station, Kovalam to get maximum recovery of stocking size prawns of two commercially important penaeid species, *Penaeus indicus* and *Penaeus monodon* by nursery rearing in nylon net cages. Six sets of rearing experiments conducted during 1978-79 in twelve nylon net cages of 5 × 2 × 1 m size set up in Kovalam Backwaters, near Madras provided information on growth and survival. The cages were stocked with 13.74 mm/0.05 gm sized *Penaeus indicus* and 12.5 mm/0.15 gm *Penaeus monodon* at the rate of 300 to 500 and 200 to 400 postlarvae per metre square respectively. The postlarvae were fed daily with flesh of clam *Meretrix casta* at the rate of 50% of their body weight. Sampling were made once in a week for growth assessment. During the harvest at the end of 30 days, survival rates of *Penaeus indicus* ranged from 70% to 90% and of *Penaeus monodon* ranged from 60% to 85%. The increments in growth of *Penaeus indicus* and *Penaeus monodon* ranged from 35.28 mm/0.81 gm to 35.5 mm/0.92 gm and 32.52 mm/0.975 gm to 37.55 mm/1.067 gm respectively.

IT IS only recently the different maritime States have evinced interest in prawn culture and it is at various levels of developmental stages in India. One of the most important steps in prawn culture is nursery management, as the successful prawn farming is preceded by an efficient nursery management.

At present, even in the few scientifically managed prawn farms in India, naturally occurring commercially important prawn larvae are collected and utilized for culture purposes. In some of the places before stocking in grow-out ponds they are reared for one or two months in nursery ponds (Chandra Bose and Venkatasamy, 1976; Verghese, 1978), plastic pools (Verghese, 1978) and bamboo cages placed in feeder channel (CIFRI, 1974).

With a view to explore the possibility of producing more quantity of quality prawn juveniles for the fastly growing prawn farming industry, attempts have been made at Tamil Nadu Mariculture Research Station, Kovalam, near Madras on nursery rearing of the two commercially important penaeid species, *Penaeus indicus* and *Penaeus monodon*, in nylon cages suspended in Kovalam Backwaters. In the present communication, the results of one such nursery rearing experiment carried out in nylon cages during 1978-79 are presented.

The authors are grateful to the Director of Fisheries, Tamil Nadu for giving permission to present this paper in the Symposium and to Shri A. Sreenivasan for his valuable suggestions and guidance.

Materials and Methods

The experiments were conducted in twelve collapsible 36 meshes/cm velon screen cages of 5 × 2 × 1 m size. The cages were fixed in 1.2 metre depth of water in muddy bottom ensuring that the bottom of the cage remained about 40 cm above the substrate and also the top of the cage was 20 cm above the water surface. Each cage had a water spread area of 10 sq. m. The debris accumulated on the sides of the cages blocking free flow of water was removed once in a week.

Prawn postlarvae having a size range of 10-15 mm were collected from the shallow margins of the Kovalam Backwaters near the culture site by velon screen drag net. From the collection, the postlarvae of *P. indicus* and *P. monodon* were segregated, measured and stocked in three different stocking densities. The postlarvae were fed twice daily with finely chopped flesh of clam *Meretrix casta* at the rate of 50% to their total body weight. Random sampling of 50 larvae for each cage was made once in a week for growth assessment. Harvesting was done at the end of 30 days and recording of growth and survival of reared prawns was made.

Environmental parameters such as, temperature, salinity, dissolved oxygen content and pH of the backwater near the culture site were recorded once in a week to correlate the factors with the growth of larvae.

Results and Discussion

Results obtained from the nursery rearing experiments are given in Table 1. Weekly observations on growth are shown in Fig. 1.

From the Table it can be seen that the survival rates of *P. indicus* were almost identical under stocking densities of 300/sq.m and 400/sq.m. However, comparatively poor survival was obtained at a stocking density of 500/sq.m. Almost identical growth was obtained under the three stocking densities.

In the other set of rearing experiments with *P. monodon* it can be seen that lower the rate of stocking, higher was the survival and vice versa. Similarly, slightly better growth of 50.03 mm/1.217 gms in the lowest stocking rate of 200/sq.m and almost identical growth (45.02 mm/1.125 gms to 46.42 mm/1.137 gms) in other two rates of stocking was obtained.

From the overall survival and growth of the two species of prawns it may be seen that stocking size prawn juveniles of 45-50 mm could be obtained in 30 days rearing in nylon cages with maximum survival. The stocking densities of 300 to 400/sq.m and 200/sq.m could be the optimum for *P. indicus* and *P. monodon* respectively for nursery rearing in cages.

It has been reported (CIFRI, 1978 ; Chandra Bose and Venkatasamy, 1976) that for well prepared nursery ponds the suitable stocking densities could be 2 to 3 lakhs/hectare with survival rates ranging from 30 to 40%. Rearing experiments at higher stocking densities 2370/sq.m in closed race ways have also been reported with 94% survival (Mock, 1973).

Under controlled conditions in plastic pools with artificial feeding, postlarvae of *P. monodon* reared at an initial stocking density of 10,000/sq.m thinned twice to half at fortnightly intervals, a survival of 75% in a total period of 60 days of rearing was obtained with final size of 45-50 mm (Verghese, 1978).

The hydrological features of the Kovalam Backwater near the culture site are presented in Fig. 2. Dissolved oxygen content during the rearing period ranged from 4.4 ppm to 6.8 ppm. Salinity fluctuated between 19.2‰ and 29‰. There were slight fluctuations in water temperature ranging between 26°C to 27.5°C. pH of the backwater near the culture site ranged from 8.6 to 8.7. It may be seen that generally the water quality was congenial during the period of rearing.

The present methods of rearing of postlarvae of *Penaeus indicus* and *Penaeus monodon* in nylon cages compare favourably because of high survival rates (70.5% to 89.167% and 60.957% to 81.25% respectively), for and better growth (49.02 mm/0.86 gm to 49.24 mm/0.97 gm and 45.02 mm/

TABLE 1. *Details of stocking density, survival and growth rate* P. monodon *in nursery rearing*

Rearing No.	Stocking density no/m²	Duration in days	Average initial length in mm	Average final length in mm	Percentage of survival %	Average daily growth rate in mm
1	2.5	28	14.0	47.2	52	1.19
2	2.5	28	16.5	66.4	68	1.78
3	5	28	14.0	58.7	35	1.56
4	5	28	14.0	45.4	40	1.12
5	7.5	28	14.0	36.8	65	0.81
6	10	29	14.0	40.9	36	0.93
7	10	31	16.5	54.4	32	1.22
8	15	30	14.0	58.4	31	1.48

1.125 gm to 50.03 mm/1.217 gm). Moreover nylon cage rearing

1. can be erected in any place of backwaters or in the rearing pond itself in fixed or suspended manner and as such no separate nursery space is necessary;
2. offers better growth and high survival rate are assured;
3. as it provides natural running water, no shortage of dissolved oxygen; carrying capacity can be increased and amount of water required does not come into consideration;
4. of whole system can be shifted from one place to another depending upon their productivity; and
5. provides less initial cost and easy construction and handling.

Thus, the observations made on the nursery rearing experiments conducted in nylon cages at Kovalam showed that nylon cages could successfully be utilised as nurseries for the rearing of prawn larvae in place of ponds.

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OBSERVATIONS ON GROWTH AND CONVERSION EFFICIENCY IN THE PRAWN *PENAEUS INDICUS* (H. MILNE EDWARDS) FED ON DIFFERENT PROTEIN LEVELS*

ABSTRACT

Diets with different percentage composition of ingredients were prepared in the form of pellets and fed to prawn. The conversion efficiency and growth rates were high in diets containing 60% protein. Survival rate of the group fed with 50% protein was higher.

THE raising of prawns to marketable size in impoundments within a short period through the provision of lowcost feed continues to be a pressing problem in aquaculture research. It is necessary to provide prawns with essential and fortified feed to boost and maintain a high growth rate within a short period in the absence of natural feeds.

In recent years sustained research efforts at developing artificial diets capable of sustaining optimum growth are in progress. (Deshimaru and Shigeno, 1972; Kanazawa *et al.*, 1970; Cowey and Forster, 1971; Sick *et al.*, 1972; Andrews *et al.*, 1972; Forster, 1972; Balazs *et al.*, 1973; Zeni Eldin *et al.*, 1973, 1976; Sandifer *et al.*, 1976; Venkataramaiah *et al.*, 1975; Katre Shakuntala and Ravichandra Reddy, 1976.)

We are thankful to Prof. R. Natarajan, Director for encouragement and facility provided. Our thanks are also due to the Annamalai University for facilities and assistance and the University Grants Commission, New Delhi for the financial support of the project 'The culture of the prawn *Penaeus indicus*', and for the award of research fellowships to two (S.S. and P.S.) of us. We are also thankful to the Evian Kyowa, Kyowa Hakko Kogyo Co., Ltd., Japan for the supply of the compound prawn feeds Crumble No. 3.

Scope

Determination of food intake, growth and conversion efficiency are known to be the best indices to evaluate the growth of organisms in a habitat. Thus, laboratory studies on growth and conversion efficiency of the decapod crustaceans are useful in promoting crustacean culture (Katre Shakuntala and Ravichandra Reddy, 1976).

Therefore the investigation was undertaken to find out the optimum requirement of protein of *P indicus*, on the basis of survival rate, growth rate and conversion ratio when fed with diets containing 40, 50 and 60% protein.

Materials and Methods

Controlled laboratory feeding experiments were conducted using 45 litre plastic tanks. Tank bottoms were left bare. Filtered sea water averaging 27°C was used in this experiment. The tanks were cleaned daily and moderate aeration was provided. Animals were quantitatively fed with the assigned diet (10% of the body weight) twice a day *i.e.*, morning and evening. Unconsumed food was removed prior to fresh feeding recourse.

Juveniles of *P. indicus* were collected from the Vellar Estuary, (opposite Biological Station) and stocked in the plastic tanks.

* Research sponsored by University Grants Commission, New Delhi.

They were acclimatised for 7 days. Each tank contained twenty prawns of body weight between 0.23 and 0.33 g. Replicates were run. These studies lasted 30 days.

The experimental diet: The experimental diet (Table 1) contained major leaf protein of *Prosopis*, *Rhizophora* and other ingredients such as prawn head, soybean, squid and clam meats as principal protein source combinations. The ingredients were combined to arrive 40, 50 and 60% protein levels and feed to the animals in the form of dry pellets. The protein was estimated by biurette method (Raymont *et al.*, 1964).

TABLE 1. *The percentage levels of protein of different ingredients in the three tested diets*

Ingredients	Diet A	Diet B	Diet C
Prosopis leaf powder	Japan formula feed (Evian Kyowa Hyowa Hakko Co., Ltd.) Crumble No. 3	35	—
Rhizophora leaf powder		—	45
Copra meal powder		5	5
Myda powder		10	5
Tapioca powder		10	20
Prawn head powder		10	10
Soy bean powder		10	5
Squid meat		5	5
Clam meat		15	5
Protein level (%) ..	60	50	40

The ingredients were mixed and then bound with starch and myda. The mixture were extruded through a chakkuli machine with an internal diameter of 1.5 mm and sun dried.

Results

Growth rate: The growth rate of juveniles of *Penaeus indicus*, as shown in Table 2 and Fig. 1 indicate that the weight increment of prawns fed with 60% protein level was better than with the other diets containing 50% and 40% protein levels. With increased

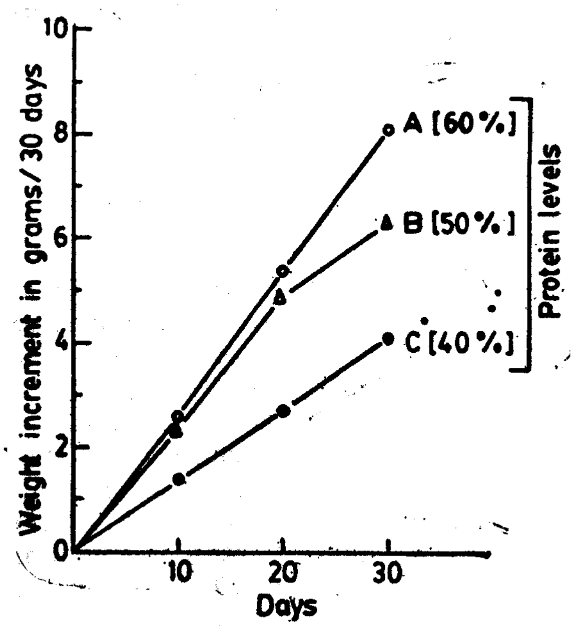

Fig. 1. Weight increment of *P. indicus* fed with diets containing 60%, 50% and 40% Protein levels.

protein levels, there is a net overall gain in mean body weight.

Survival rate: The highest survival rate of 100% was noticed in the group fed with 50% protein level. The lowest survival rate of 90% was noted in prawns fed with 40% protein levels.

TABLE 2. *Growth of* Penaeus indicus *when fed with the three tested diets*

Diet	Conversion ratio*	% weight gain per day/per animal
A. Japan formula feed (Evian Kyowa) Crumble No. 3	0.98	2.72
B. *Prosopis spiecgera* leaf pellets	1.12	2.42
C. *Rhizophora* leaf pellets	1.14	1.89

* Dry food consumed/live weight gain.

Conversion ratio: Best conversion ratio of 0.98 was obtained with diets containing 60% protein, when compared to other diets containing 50% and 40% protein levels (Table 2).

Discussion

The present study has shown that *Penaeus indicus* needs a high protein level for increase in weight. Comparison of present results with those reported already have shown that, rapid growth rate of *P. japonicus* occurred when test diets contained more than 60% protein (60% — 75%) (Deshimaru and Shigeno, 1972). Andrews *et al.* (1972) considered that 30% protein was optimal for 4 g juveniles. Lee (1971) stated that the optimum protein level for *P. monodon* was 40-50%, but the growth rate was not proportional to the protein levels. Forster and Beard (1973) indicated that the protein levels compatible with maximum or near maximum growth are between 30 and 40% protein in *Polaemon serratus.*

Venkataramaiah (1975) stated that best growth rate was obtained with food containing 40% protein. But in the case of *P. aztecus*, when the dietary protein levels were increased to 50, 60, 70 and 80%, there were corresponding decrease in growth rates. Colvin (1976) stated that in the case of *P. indicus* live weight gain at levels ranging from 21-53% crude protein, was greatest with a 43% protein diet, although efficiencies of protein utilization (recorded as P.E.R. values) declined with successive increase in dietary protein in South African waters. Shewbart *et al.* (1973) proposed optimal protein levels of 22.5%—30.5% for 3-4 g shrimp, while 35% protein seemed to reduce growth potential. Balazs (1973) reported that the growth rate of *P. japonicus* appeared to increase with increasing dietary protein levels, 40% being optimum.

The present study has shown that in the juveniles of *P. indicus*, growth rate increases with increasing protein levels and a higher growth rate is possible when fed a diet containing 60% protein.

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PRAWN AND FISH CULTURE IN POLYTHENE FILM LINED PONDS AT CALICUT SEA SHORE

ABSTRACT

A fish farm with polythene film lined ponds is developed on the sea shore of Calicut for culturing fishes and prawns. Commercially important prawns like *penaeus indicus, Metapenaeus dobsoni* and *M. monoceros* and the fishes *Chanos chanos, Mugil cephalus, Liza subviridis, Liza parsia, Lates calcarifer* and *Megalops cyprinoides* were cultured in these ponds. Suitability of polythene film lined ponds for fish and prawn culture is discussed.

FISHES AND PRAWNS were cultured in various ecological environments. Apart from the conventional and traditional fish farms many contraptions like cages, fish enclosures and fish pens are also developed. Wheeler (1966) and Tabb *et al*. (1969) reared fish and prawns in the polythene lined ponds in U.S.A.

To find out the feasibility of utilising the fallow sandy sea shore for fish culture, experiments were conducted in the Calicut sea shore by lining the ponds with polythene film of suitable thickness and stocking them with fishes and prawns. The polythene film lining effectively prevents the seepage of water.

Materials and Methods

Ponds measuring 0.02 to 0.1 ha were made in the Calicut sea shore in 0.4 ha area (Plate I A-D). The ponds were given 60° slope. The black polythene film of 150 μ thickness and of width 3.7 to 6.1 mm was used for lining the ponds. The film of required width were made by fusing the free ends of the film by using a hot iron over a cellophane paper. All the hard objects were removed from the pond before spreading the film. The free ends of the film were properly anchored along the border of the pond in a trench of about 30 cm wide and 30 cm deep. Beach sand was spread on the bottom of the pond. This layer of sand prevented the absorption of the sun light by the black film and provided substratum for the prawns and fishes.

Sea water was pumped by a 3 H.P. diesel pump kept on the sea shore. The foot valve and the distal end of the delivery pipe were properly covered with a velon screen net of 1 mm mesh size so as to prevent the entry of fishes and prawns into the ponds.

The ponds were stocked with seeds of *Penaeus indicus, Metapenaeus dobsoni, M. monoceros, Chanos chanos, Mugil cephalus, Liza subviridis, Liza parsia, Lates calcarifer* and *Megalops* *cyprinoides* collected from the surf, low lying areas and estuaries with a rectangular drag net made of velon screen.

The prawns and fishes were fed with various artificial feed. Till the prawns attained 30 mm length, they were fed with dry fish meal at the rate of 1/5th of the body weight twice a day. The fish meal was prepared by pulverising dry trash fish, waste and prawn heads. Prawns after 30 mm length, the carnivorous fishes and mugils were given fresh minced prawn head peelings at the rate of 1/10 of the body weight. The feed for milk fish was prepared by boiling broken rice, prawn head and sardine oil mixed at the ratio of 10 : 1 : 0.1 and fed at the rate of 1/10 of body weight. In one of the experiments prawns were also fed with this food.

Results

Table 1 summarises the results of various experiments with different stocking rates and species composition. The growth rate of prawns were found to be slow when compared to that in natural environment. But very high survival rate was observed in short-term culture experiments with the duration of less than 120 days. Survival rate for the prawns was found to be low when the stock was kept for more than 150 days.

In the polythene film lined ponds *P. indicus* grew to 136 mm weighing 16 g during 272 days with 32% survival, whereas it attained 98 mm weighing 4.2 g in 98 days with 97% survival. Growth rate was also found to be faster in the first four months. *M. dobsoni* and *M. monoceros* were found to attain 87 mm weighing 5.5 g and 5.8 g during 288 days. Prawns were also cultured along with *Mugil* spp. to observe the growth of prawns when stocked with other compatible fishes. In the polyculture experiments also the growth of prawns were found to be more or less same as in the monoculture experiments (Table 1).

L. subviridis attained a length of 207 mm weighing 78.5 g in 182 days with a high survival rate of 92%. *M. cephalus* grew to 376 mm weighing 533 g during the same period. But due to the non-availability of the seeds of *M. cephalus* further experiments with this species could not be designed. *L. parsia*, a slow growing species attained 129 mm only weighing 20.8 g during 288 days. The growth of *C. chanos* was found to be good in this system. It attained 357 mm weighing 453 g in 234 days with 96% survival. The growth rate was slow after 5 months. *Calcarifer* was also found to grow well. It attained 370 mm weighing 600 g during the period of 520 days with a high survival rate of 100%. *M. cyprinoides* attained 185 mm from 95 mm during 190 days with 100% survival.

It was observed that the growth rate was more or less same for the various artificial feeds tried (Tabel 1).

Discussion

George *et al.* (1968) found that female *P. indicus* attained a length of 141-145 mm during the first year of its growth in the natural conditions. During the culture experiments by the Central Marine Fisheries Research Institute Cochin (CMFRI, 1978) *P. indicus* and *M. dobsoni* were found to grow to 41-145 mm and 36-70 mm respectively in paddy-cum-prawn filteration ponds during 152 days, whereas in the perennial ponds *P. indicus* attained 121-150 mm weighing 17 g with a survival rate of 75% during 105 days. However in another pond *P. indicus* and *M. dobsoni* attained an average length of 96.2 mm and 71.7 mm weighing 10.5 g and 1.8 g respectively for 122 days. Mohammed *et al.* (1980) recorded a growth of 139 mm for *P. indicus* in the salt pan reservoirs of Tuticorin with a stocking rate of 26,666/ha during 154 days. When compared to the growth attained by the

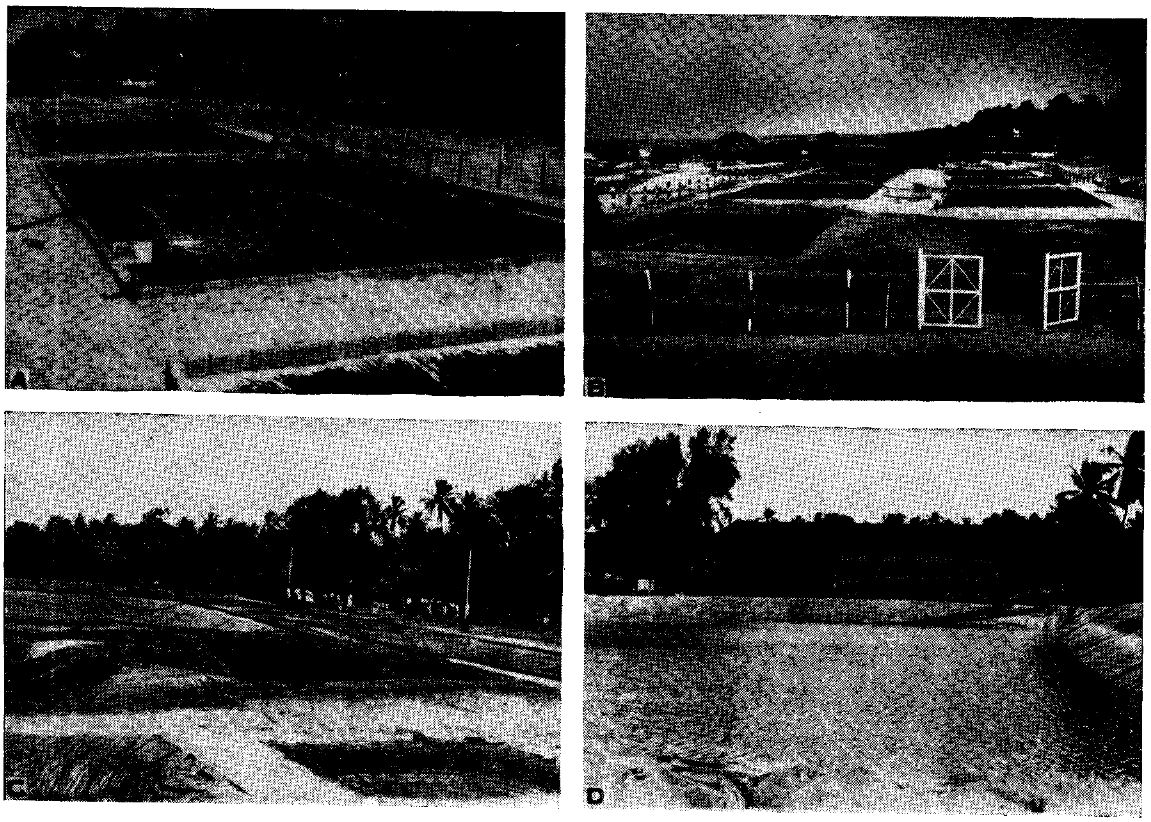

PLATE 1. A. 0.01 ha polythene film lined pond ; B & C. View of the polythene film lined ponds ; D. 0.1 ha pond.

TABLE 1. *Details of the fish and prawn culture experiments in polythene film lined ponds*

Species	Area (ha)	No. stocked	Rate of stocking/ ha	Duration (in days)	Length stocking (mm)	Harvest (mm)	Wt. at harvest (gm)	Survival rate %	Food	Salinity (ppm)	Dissolved oxygen (ml/l)
Penaeus indicus	0.03	440	14,700	272	40	136	16	32	Peeled prawn head at 10% of body wt.	4.6-56.0	2.5- 5.0
P. indicus	0.02	1,296	64,800	155	40-60	98	4.2	97	,,	4.6-56.0	2.6- 5.3
P. indicus	0.02	1,200	56,000	246	20	115	15	45	Rice boiled with prawn head, sardine oil at ratio 100 : 10 : 1 at 10% of body wt.	5.7-5.20	2.5- 5.0
P. indicus	0.02	1,700	85,000	245	7-8	120	15	24	,,	5.7-55	2.5- 5.2
Metapenaeus dobsoni		342	17,100	,,	7-8	91	3.6	28	,,		
Liza subviridis		120	6,000	,,	30	207	76	96	,,		
P. indicus	0.06	540	9,000	288	40-50	137	16	8.5			
M. dobsoni		2,650	44,833	,,	40-50	87	5.5	2.8	Peeled prawn		
M. monoceros		250	12,500	,,	40-50	87	5.8	2.3	head at 10%		
Liza parsia		214	3,566	,,	18-19	129	20.8	90	of body wt.	0.9-47.5	2.9- 6.3
Liza subviridis		101	1,683	,,	18-19	205	116	95			
Valamugil scheli		13	216	,,	18-19	207	77.8	100			
Liza subviridis	0.02	30	1,500	182	10-13	207	78.5	92	Peeled prawn		
Mugil cephalus		2	200		10-12	376	533	100	head at 10% of body wt.	4.6-52.0	2.6- 5.2
Chanos chanos	0.02	26	1,300	234	10-12	357	453	96	Boiled rice, fish meal and	5-42.0	3.0- 6.0
Liza subviridis		200	10,000		18-19	191	110	80	sardine oil at 100 : 10 : 1 ratio at 10% of body wt.		
Lates calcarifer	0.02	25	1,250	520	10-13	370	600	100	Peeled prawn heads at 10%		
Liza subviridis		66	3,300	272	23-33	217	82.5	80	of body wt.	7-42.0	2.5- 5.7
Megalops cyprinoides	0.02	125	6,250	190	95	185	53	100	Peeled prawn heads at 10% of body wt.	2.0-15.0	0.7-7

prawns in the natural systems, the gorwth of prawns in the polythene film lined pond is less, but the growth of fishes in this system is quite comparable to that in natural ponds. Ramamurthy *et al.* (1978) observed that *M. macrolepis* (*L. subviridis*) and *Chanos* attained a length from 40 to 220 mm and 249 mm during 191 and 111 days respectively at a stocking rate of 1400/ha and 1000/ha in the brackishwater ponds near Mangalore. *L. subviridis* attained a length of 207 mm and *Chanos* 250 mm during 182 and 96 days respectively in the polythene film lined ponds at a stocking rate of 1500/ha and 1300/ha (Fig. 2). It may be observed that though the growth of *L. subviridis* in the present study is comparable to that of the brackishwater natural ponds, the growth of *Chanos* is found to be better in the polythene film lined ponds. The growth of *L. calcarifer* and *M. cyprinoides* were found to be from 10-13 mm to 370 mm weighing 600 g in 520 days and 95 to 185 mm weighing 53 g in 190 days respectively.

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EFFECT OF STOCKING DENSITY AND SIZE ON *PENAEUS MONODON* (FABRICIUS) POSTLARVAE IN NURSERY REARING EXPERIMENTS

ABSTRACT

Experimental nursery rearing of *Penaeus monodon* postlarvae of 14-16.5 mm size, were conducted in well prepared 200 m^2 brackishwater nursery ponds, under different stocking densities of 2.5 to 15 number/m^2 without supplementary feeding. During the rearing operation extending to 28 to 31 days and survival rates ranged between 30 and 68.4%, the lowest observed being for the highest stocking density and the highest for the lowest stocking density. The average final size attained under different stocking densities were 47.2 mm and 66.4 mm for 2.5 No/m^2; 45.4 mm and 58.7 mm for 5 No/m^2; 36.8 mm for 7.5 No/m^2; 40.9 mm and 54.4 mm for 10 No./m^2; and 58.4 mm for 15 No/m^2. The growth rates observed were found to be independent of the stocking density until one month of rearing. Weekly growth pattern in relation to the physico-chemical parameters of the pond water and the possible means to increase survival rates are discussed.

PENAEUS MONODON (FABRICIUS) is one of the fastest growing penaeid prawn, suitable for culture in India and other Asian and South East Asian countries. In the traditional culture systems and during the earlier stages of scientific culture practice, the collected postlarvae were directly released in the larger impoundments, which eventually led to poor survival and growth, owing to competition, predation and polution. Therefore there is a need for nursery rearing of prawn prior to stocking. The present communication summarizes the results of a series of nursery rearing experiments conducted at Kakdwip Research Centre, during 1977-78, at different stocking densities.

The authors gratefully acknowledge Shri B. B. Das and Shri D. Sanfui for their help in analysing the pond water during the study.

Materials and Methods

Six ponds of 200 m^2 were used for the rearing. A total of eight nursery rearings were conducted.

Stocking densities tried were 2.5 to 15 No/m^2. Stocking materials were either freshly collected postlarvae (12-16 mm) or postlarvae conditioned in plastic pools for 10-15 days (14-20 mm). The duration of rearing varied between 28 to 31 days.

No supplementary feeding was provided during the rearing. Weekly sampling was done by scoop netting using hapa nets, under the submerged leaves, where the prawns adhere to.

The physico-chemical parameters of pond water such as salinity temperature and dissolved oxygen were analysed weekly by standard methods.

Results and Discussion

During the rearing period, temperature ranged from 28.5° to 35°C ; salinity from 4 to 19.16‰ and dissolved oxygen from 6 to 12.44 ppm. There was no visible influence of physico-chemical parameters of water over the survival and growth of the prawn. The details of all the rearings are presented in Table 1. The present study revealed that, the survival rate depends on stocking density. The minimum survival rate observed was 31% for the density of 15 No/m^2. For 2.5 No/m^2 maximum survival of 68.4% was observed. This can be attributed to the fact that, with high density, lack of available food and space leads to increased canibalistic rate among the prawns. Growth rates are observed to the independent of stocking density but dependent on stocking size. At an uniform stocking density of 2.5 No/m^2 and duration of 28 days, directly stocked postlarvae attained 47.2 mm and conditioned postlarvae attained 66.4 mm, with the average daily growth increment of 1.19 and 1.78 mm respectively. At 10 No/m^2 the lengths attained were 40.9 and 54.4 mm respectively. Therefore it can be concluded that in nursery rearing of *P. monodon* survival rate is dependent on stocking density and growth rate was dependent on stocking size.

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ABSTRACTS OF PAPERS RECEIVED FOR THE SYMPOSIUM

STUDIES ON JUVENILE FISHES AND PRAWNS OF BHIMILIPATNAM BACKWATERS

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Bhimilipatnam Backwaters support a small-scale fishery for juvenile fishes and prawns throughout the year. Cast net whose catches usually comprised more than 50% of the juvenile prawns, is the chief gear besides dip net and stake net employed in the fishery. *Liza macrolepis, Mugil cephalus* and *Valamugil* sp. among mullets, *Penaeus indicus, Metapenaeus dobsoni* and *M. monoceros* among prawns were the important species contributing to the fishery and were available throughout the year. The seasons of abundance of these species were : February-June and November for *L. macrolepis* ; February-May and July-September for *M. cephalus* ; February-April for *Valamugil* sp. ; January-April and August-October for *P. indicus* ; April-June for *M. dobsoni* and February-June and November-December for *M. monoceros*. The size range of *L. macrolepis* was 20-175 mm ; *M. cephalus* 20-250 mm ; *Valamugil* sp. 20-200 mm ; *P. indicus* 15-90 mm ; *M. dobsoni* 15-60 mm and of *M. monoceros* 15-75 mm. During September-November, the postlarvae of *P. indicus, P. monodon, M. dobsoni* and *M. monoceros* were encountered in considerable numbers in the backwaters.

SEASONAL FLUCTUATION OF PRAWN AND FISH SEED AND ZOOPLANKTON IN THE SURF REGION OF THE SEA AT WEST HILL, CALICUT

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Observations on the seasonal fluctuation of prawn and fish seeds and of the zooplankton in the surf region of the sea at West Hill, Calicut were made from June 1975 to June 1979. Occurrence of large number of postlarvae of *Penaeus indicus, P. monodon, Metapenaeus dobsoni* and *M. monoceros* was recorded for the first time from the West Hill surf. During the period of observation, two peaks of occurrence of *P. indicus* and *P. monodon*, one during March-April and the other in November-December were noticed. Peak abundance of *M. dobsoni* postlarvae was observed in September-November and that of *M. monoceros* during June-August.

Among fish seed, *Mugil dussumieri* and *M. tade* occurred throughout the year with peaks in March and October, *Chanos chanos* and *Lates calcarifer* fry were collected during March-April. Leptocephalus stages of *Megalopes cyprinoides* and *Elopes machinata* were collected throughout the year with a peak during August. *Ambassis gymno-*

cephalus fry occurred round the year with peak during October to December. *Engraulis tri* was encountered in all the months with peak during October-March. Fry of *Caranx malabaricus* was found in April-March and November-January. *Sillago sihama* was mainly obtained in January-February and in October. Fry of other fishes such as *Johnieops sina*, *Polynemus plebius*, *Therapon jarbua* and Gobids were also recorded.

In zooplankton *Lucifer* sp. occurred throughout the year, peak period of abundance being February-May and November-December. *Acetes* sp. was found mainly during April-May, mysids from May to January and chaetognaths in June. Blooms of *Hornellia marina* and *Pleurobrachia* sp. were found during August to December/January, while those of *Noctiluca* and *Hemidium nasulam* were recorded in August and November respectively.

Salinity of the surf water varied from 24.7 to 35‰, whereas the dissolved oxygen content and temperature fluctuated between 1.8 to 5.8 ml/l and 24°C - 32° C respectively.

ON THE LOCATION OF A NURSERY GROUND OF *PENAEUS SEMISULCATUS* DE HAAN ALONG THE TIRUNELVELI COAST, TAMIL NADU

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Penaeus semisulcatus de Haan contributes to a fishery of considerable magnitude on the south-east coast of India, particularly in the Gulf of Mannar. The species is also suitable for intensive culture. During the course of investigations on the prawn fishery resources of the Tirunelveli Coast, a natural ground where the juveniles of the species occurred in large concentration was located in the shallow inshore sea, between Pattanamarathur and Tuticorin, covering a coastline of about 20 km. The ground is characterised by sandy bottom with rocky patches and corals covered with a thick growth of seaweeds. The juveniles from this area are fished throughout the year by an indigenous gear known as 'Ola Valai' operated in the shallow waters within 2 m depth. In 1978-79 a total quantity of 57 tonnes was caught from this region. The peak abundance was in November-January and June-July. The size ranged from 40 mm to 150 mm total length, majority measuring less than 100 mm. The possibility of utilising the area for seed collection of the species for developing intensive culture practices are discussed.

DISTRIBUTION AND ECOLOGY OF POSTLARVAE OF THE GENUS *PENAEUS* IN PULICAT LAKE

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Distribution pattern, relative abundance, immigration and ecology of the postlarvae of *Penaeus indicus*, *P. monodon* and *P. semisulcatus* in the Pulicat Lake were studied on the basis of the data collected from 1973 through 1975 from the surf region in the inshore waters of Pulicat and from different zones inside the lake. In the inshore waters the postlarvae

of *P. indicus* occurred abundantly during August-October and from January to April; those of *P. monodon* from January to March and from October to December and those of *semisulcatus* from January to June and in October. While the postlarvae of *P. indicus* and *P. semisulcatus* did not show any significant correlation with temperature, salinity and dissolved oxygen, *P. monodon* postlarvae indicated a negative correlation with salinity and a positive correlation with oxygen. Immigration of postlarvae into the lake was found to be in greater intensity in high tides, spring tides, full moon and new moon days and night hours. Postlarval density per unit area was higher in the southern sector throughout the year as compared to that in the northern sector and was found to be influenced by the tidal circulation, temperature, salinity and oxygen characters of the two sectors. *P. monodon* was encountered in salinities as low as from 0.8‰ to as high as 52.7‰ while that of *P. indicus* from 2.0‰ to 45.0‰. Although *P. semisulcatus* population occur in the lake in the salinity range of 5.52‰ to 39.0‰, they were absent in the northern sector during monsoon and premonsoon months. The postlarvae of all the species were found to prefer areas with thick cover grass and algal beds.

Importance of light in the diurnal movement of the postlarvae, their predation by the carnivorous teleosts particularly the perches and catfishes and the competition existing among the postlarvae and juveniles of fishes and prawns for food and shelter in the lake eco-system were discussed.

SEED PRODUCTION IN CAPTIVITY OF THE GODAVARI PRAWN *MACROBRACHIUM MALCOLMSONII* (H. MILNE EDWARDS)

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The giant Godavari prawn *Macrobrachium malcolmsonii* (H. Milne Edwards) is a potential competitive species to its closely allied but more popular *M. rosenbergii* (de Man) which is at present dominating in freshwater prawn culture activities.

The present work deals with mass culture of *M. malcolmsonii* from egg to juveniles/seed stage at yard scale level. The juveniles thus produced have been released in farms in Maharashtra for field trials. Various aspects of seed production and their constraints have been discussed. The results of this work indicate the possibility of developing a viable egg-to-egg culture technology in the near future, of this prawn.

The yard scale experiments were conducted following static culture system with periodical exchange of water in flat-bottom, cylindrical plastic pools of diameter × height (in cm) 120 × 60 ; 180 × 60 and 300 × 60 respectively. The larvae pass through 19 to 20 moults before attaining postlarval stage. About 20 ppt salinity was found to be favourable optimum for rearing. Though various feeds such as fresh fish roe, poached hens egg with vitamin-mix+prawn powder, clam meat, and zooplankton were tried, *Artemia* nauplii, at least in early stages were found to be essential for healthy growth and proper metamorphosis of larvae. The height of water column, from about 5 cm at the time of holding the berried

females and increased gradually on hatching, was maintained at about 20 cm which was convenient for management both for aeration as well as siphoning, etc. since the pools were kept at ground level. The post-larvae readily take any feed offered during the first few days but subsequently show some kind of selectivity for feeds. Adequate shelters by way of small earthen tile pieces, stones or weeds were essential in post-larval rearing.

The preliminary studies also revealed that the species possesses an inherent euryhaline adaptability even as adults and thus can be profitably tried for culture in low saline waters of the coastal areas.

SEED PRODUCTION OF *MACROBRACHIUM ROSENBERGII* UNDER STATIC GREEN WATER SYSTEM

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A new approach to the seed production of *Macrobrachium rosenbergii* has been successfully experimented at the hatchery of the Faculty of Fisheries and Marine Science, University of Agriculture, Malaysia. This method involved the use of 'green water' with the minimum of water change throughout the experiment. *Macrobrachium* larvae were raised in fibreglass tanks of 130 litres capacity at 6 ppt and 12 ppt salinities and at the stocking rate of 18 to 22 larvae per litre. This 'green water' consisted of unicellular algae such as *Chlorella* spp. and *Scendesmus* spp. These algae were efficient in the removal of toxic metabolites from the culture medium. The larvae were given egg custard except the last feeding in the evening where *Artemia* naupli were given as feed. When *Artemia* was given, both the nauplii and their egg cases were introduced into the larval tanks. The egg cases were found to enhance the survival rate of the *Macrobrachium* larvae. A survival rate of 36-39% was achieved and the first post-larva emerged after 25 days.

POSTLARVAL AND JUVENILE COMPARISON OF THE TWO GIANT FRESHWATER PRAWNS *MACROBRACHIUM MALCOLMSONII* (MILNE-EDWARDS) AND *M. ROSENBERGII* (DE MAN) — AN AID IN SEED SELECTION

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In India, the two giant prawns *Macrobrachium rosenbergii* and *M. malcolmsonii* are at present considered as candidate species for freshwater prawn culture, the former being already cultivated in various parts of the country since ages while the latter is still under culture trials. However, in both cases the seed is collected entirely from nature which necessitates the authenticity of the identification of the desired seed. This selection is

rendered difficult especially in areas where both the species occur together like in Vellar Estuary along the southeast coast of India, since they resemble each other even at post-larval and juvenile stages. In fact, in nature both the above species, either individually or together, are generally found along with several other *Macrobrachium* and/or Atyid species whose young ones or sub-adults confusingly resemble the post-larvae or juveniles of the above candidate species.

The present paper gives the comparison of post-larval and juvenile stages reared in captivity of *malcolmsonii* and *rosenbergii* which will aid in selection of species for stocking.

The post-larvae are morphologically almost similar in both *M. rosenbergii* and *M. malcolmsonii* but those of *M. malcolmsonii* are comparatively bigger (10 to 12 mm in *malcolmsonii* but 9 to 9.5 mm in *rosenbergii*) and also differ distinctly in colour pattern. In fact, *M. malcolmsonii* post-larvae can be differentiated easily not only from *M. rosenbergii* but also from number of other species of *Macrobrachium* (authors, unpublished) by their characteristic horizontal band of alternating black and golden yellow dots, at the junction of carapace and abdomen, besides other chromatophores. This characteristic band continues even in juveniles of *M. malcolmsonii*.

PROSPECTS FOR PENAEID SHRIMP CULTURE IN THE ARABIAN GULF

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The relative state of development of shrimp culture int he Arabian Gulf is described with details of culture systems currently adopted or used in the past. The factors effecting the choice of culture systems in the regions, particularly those related to the arid nature of the environment, have been considered and the projected costs for the different systems compared. Commercial penaeid shrimp culture prospects in the Arabian Gulf are contrasted with those in other arid regions.

PRAWN CULTURE IN BRACKISHWATER : PROSPECTS AND CONSTRAINTS

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The relevant aspects to be considered before taking up vertical and horizontal expansion of prawn culture are, a scientific survey of suitable sites ; availability of adequate numbers of seed for stocking and designing of ponds. The site chosen must have desirable tidal amplitude or circulation, with optimum salinity ranges and suitable soil which would be productive and which would be physically fit for retaining water. Prawn farming requires seed at very high densities (average 50,000/ha/crop) and a modest 1 lakh seed would be needed to raise 2 crops/ha/year. Thus even for 1000 ha the seed required would be 100 million. A

large number of hatcheries have to come up and mass breeding and rearing techniques perfected on a commercial scale.

Intensive culture would require fertilization/ feeding or both and optimum fertilizer inputs and suitable feeds have to be formulated. Legal and social aspects are also important factors to be taken note of. Estuarine pollution is another constraint to be overcome. Suitable economic designs for construction of prawn farms must be evolved. Credit is not the least important of constraints.

NOTES ON PRAWN FARMING IN THE LOW SALINE ZONE OF THE MATLAH ESTUARY

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Investigations on the culture of tiger prawn, *Penaeus monodon* Fabricius carried out in 10 ha brackishwater fish farms in the low saline zone of the Matlah Estuary in lower deltaic West Bengal, revealed important information and data on prawn farming techniques. The enclosed farms are replenished at regular intervals by nutrient rich tidal water from the Matlah Estuary. The water salinity inside the farm varied from traces in monsoon to 12.0 ppt in summer and the temperature ranged between 19.5°C and 35.5°C. The D.O. was between 3.0 and 13.0 ppm and pH 7.1 and 8.7. The organic carbon of the soil was about 1.44% and the average values of nitrogen and phosphate was 38 mg/100 g and 8.0 mg/100 g respectively. Postlarvae of *P. monodon* were selectively stocked in the portion of the farm ponds where certain types of aquatic bushy plants were grown for epiphytic growth of diatoms and planktonic organisms. The redox potential studies were undertaken to keep a check on reduction factors of the ecosystem. The results of experiments indicated that a production of about 2 tonnes per ha could be raised in 2 crops in 7 months.

GROWTH AND PRODUCTION OF *PENAEUS MONODON* FABRICIUS IN SHORT-TERM FIELD REARING EXPERIMENTS

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Results of 18 experimental short-term rearings of *Penaeus monodon* in 200 m^2 ponds were presented and discussed. Culture duration varied between 65 and 185 days. The salinity of the pond water ranged from traces to 20 ppt. Stocking densities tried were 1 to 7.5 nos/m^2. Management practices followed were the same for all the rearings. Generally faster growth was observed during January to May, when the temperature and salinity of the pond water were gradually increasing. Growth rates in relation to stocking density, survival, stocking size and temperature/salinity are discussed. During 1977-78 the production of *Penaeus monodon* through three crops in four ponds were, 1189 kg/ha ; 583 kg/ha ; 464 kg/ha and 486 kg/ha. The possible factors affecting the production and leading to inconsistencies among different ponds are analysed and discussed.

LABORATORY REARING OF THE LARVAE OF *PARAPENAEOPSIS ACCLIVIROSTRIS* ALCOCK

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Parapenaeopsis acclivirostris spawned in the laboratory and the larva were reared upto the post-larval stage under controlled conditions. The results of the rearing experiment are reported in this paper along with a detailed description of the various larval stages of the species. The larvae passed through 6 naupliar, 3 protozoeal and 6 mysis stages before reaching the post-larval stage which was obtained in 19 days after spawning.

CULTURE POSSIBILITY OF A PALAEMONID PRAWN *MACROBRACHIUM CANARAE* (TIWARI)

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The freshwater palaemonid prawn *Macrobrachium canarae* (Tiwari) forms one of the species of the genus in local prawn catch at Karkal in the South Kanara District of the Karnataka State and serves as a poor man's shell-fish delicacy in the area.

The present paper deals with the metamorphosis in the laboratory of *M. canarae* which is partially abbreviated comprising only 3 zoeal and 1 post-larval stages, requiring about 7 days, at rearing temperature of 25° to 27° C. The short and uncomplicated life-history with high survival percentage of larvae and post-larvae coupled with the adult features like fairly good size (about 6 cm) apparently low fecundity (50 to 100 eggs of fairly big size) compensated by high recovery percentage of post-larvae (about 5 mm long) and its status in local fishery, makes it worthwhile for culture attempts.

The proximity of the occurrence of *M. canarae* to the South Kanara Coast and natural hardiness of the species particularly with reference to salinity both in adult and larval phases render this otherwise freshwater species suitable even for coastal aquaculture.

LABORATORY CULTURE OF *MACROBRACHIUM EQUIDENS* (DANA)

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The caridean prawn, *Macrobrachium equidens* was successfully cultured from egg to adult under laboratory conditions. Eggs hatched out into zoea in a low saline medium of 10-15‰. The larval development was completed in 25-45 days. The maximum survival of larvae was found at a salinity range of 20-25‰. Ten well defined zoeal stages were distinguished

during development and were described in detail. The first post-larva took three months to attain maturity when the prawn measured 41-48 mm in total length. The incubation period was 16 days. After hatching of eggs, the female prawn got berried again within nine days.

AN ATYID SHRIMP *CARDINA KEMPI* JALIHAL, SHENOY AND SANKOLLI—A PROSPECTIVE SPECIES FOR CULTURE

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The freshwater prawn fishery in the Dharwad area of the Karnataka State comprises the Palaemonid genus *Macrobrachium* and the Atyid genus *Caridina*. One of the two *Caridina* species, namely *C. kempi*, occurring in this area contributes to about 35% of total catch and is relished both in fresh as well as sundried condition. The role of this species in the local fishery and its features like small size (30 mm), fairly good fecundity (250-600 eggs) compared to its small size, breeding habits of breedings throughout the year with short interbreeding periods, hardiness with reference to low DO level, to wide ranges of temperature (18° to 35°C) and considerable ranges of salinity (0 to 25 ppt) merit its consideration for culture possibilities both in inland and coastal low saline waters, as candidate species and also as forage organism. Life history studies were, therefore, undertaken both in fresh and saline water with a view to understanding the basic culture requirements.

The larvae of *C. kempi* pass through 6 zoeal and 1 or 2 'prepost-larval' stages before metamorphosis which is described in the present paper. The larval duration is about 11 days at 26° to 28°C in freshwater, while in saline waters duration is cut down to 9 days, metamorphosis completing upto salinity range of 20 ppt without any deviation in number of stages.

Besides the simple larval rearing, the adult tolerance to salinity as high as 25 ppt and also the capacity of the species for completion of development in about 20 ppt (even without acclimation) indicate the possibility of utilizing this shrimp both for coastal as well as inland aquaculture.

LABORATORY CULTURE OF A POSSIBLE FORAGE SPECIES OF A MARINE PRAWN *PALAEMON (PALAEMON) DEBILIS* DANA

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Exploration and exploitation of forage species is as integral a part of aquaculture as the candidate species, particularly in mariculture. During the work on marine caridean prawns of the Karwar area, *Palaemon (Palaemon) debilis*, a widely distributed Indo-Pacific species,

was found to be a common prawn occurring in the area. The hardiness of the species with reference to salinity, occurrence in both intertidal and mangrove areas, its small size (upto 40 mm), fecundity (average 300 eggs), and fairly easy larval rearing merit its consideration as a culturable forage species in the cultivation of larger, carnivorous marine/brackishwater candidate species.

Since the life history studies form an essential prerequisite for culture experiments the present work on development of *P.* (*P.*) *debilis* in the laboratory was carried out. The life history comprises 13 zoeal and 1 post-larval stages.

ON THE AVAILABILITY OF FOOD FOR PRAWNS IN SOME TIDAL PONDS OF COCHIN BACKWATER AT RAMANTHURUTH

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Four tidal ponds in Ramanthuruthu Island near Cochin Harbour entrance afforded excellent opportunity to study some of the environmental requirements of commercially important species of prawns and their food organisms. As part of the programme in qualitative and quantitative study of the macrobenthos were carried out in detail. Benthic organisms were less abundant in the pond which maintained large prawn population and may largely be due to predation. Although they were more abundant in the remaining ponds their composition was not uniform. Polychaetes and gastropods were better represented in ponds 1 and 3. The abundance of *Apseudes chilkensis* in pond 2 and their relatively poor representation in the adjoining ponds was noticed during the entire period of observation. Its abundance seems to be indicative of greater reducing conditions arising from accumulation of dead and decaying plant and animal matter.

Number of benthic species in the area sampled were relatively small suggesting a short food chain. Seasonal variations of the major groups of organisms and their relation to food and feeding of prawns in these ponds were discussed.

INVESTIGATIONS ON THE USE OF *MOINA* AS FOOD FOR REARING JUVENILES OF *METAPENAEUS AFFINIS*

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The artificial foods that have been formulated and tested have generally yielded poor growth in the developing shrimps. Hence, an attempt was made to culture juveniles of *Metapenaeus affinis* on the freshwater plankton *Moina*. Juveniles of *M. affinis* weighing 2.68 ± 0.802 mg were stocked at the rate of 100 individuals/25 l seawater (35‰ S) in aquarium tanks (area 288 cm²) and reared on a diet of frozen *Moina* offered *ad libitum*. At the end of 30 days feeding period, the juveniles were found to consume 3.59 ± 0.354 mg *Moina*/

juvenile/day and exhibited a growth increase of 1.28 ± 0.399 mg in weight/juvenile/day which was equivalent to 35.65% of the consumed food. In 50 days, 1 kg of initially stocked juveniles would 66.85 ± 6.516 kg of frozen *Moina* to produce 23.77 ± 7.446 kg of new juvenile flesh.

FOOD CONVERSION IN THE SHRIMP *METAPENAEUS MONOCEROS* (FABRICIUS) FED ON MANGROVE LEAVES

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Feeding experiments were carried out on *Metapenaeus monoceros* using mangrove leaves as one of the chief ingredients of food in combination with rice bran. Juveniles of *M. monoceros* were divided into three groups and maintained in brackishwater under laboratory conditions (15‰ salinity and 28 ± 1°C). Shrimps belonging to group I were fed on withered leaves of *Rhizophora mucronata* (60%) and rice bran (40%). Groups II & III shrimps were fed on 'partially' and 'completely' decomposed *R. mucronata* leaves mixed with rice bran in the same proportion as that of group I. Caloric value of the shrimps before and after the experiment was determined and caloric gain was taken as an index of growth. Energy determinations of the feed, faecal matter and the shrimps were made using bomb calorimetry in experiments lasting 20-30 days.

Of the three groups of shrimps, maximum conversion efficiency (K_1-15% & K_2—16%) was recorded in group III. Assimilation efficiency (92%), relative growth rate (37 mg/W^-/D) and faecal output, as a percentage of consumed food were similar in groups II and III. Conversion efficiency (K_1—6% & K_2-7%), assimilation efficiency (85%) and relative growth rate 10 mg/W^-/D) were found to be lower in group I shrimps fed on withered mangrove leaves. Group III shrimps consume less food than the other two groups, while group II consumed maximum food but the efficiency of conversion was less than that of group III.

Differences in conversion efficiency obtained in the three groups of shrimps were attributed to biochemical composition of the feeds which varied as the decomposition process proceeded. Results of this study have been compared with those reported by other authors.

BIOKINETIC RANGE OF TEMPERATURE FOR THE PRAWN, *METAPENAEUS MONOCEROS* (FABRICIUS)

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The interaction between living organisms and their environment is an important aspect in aquaculture. Temperature is one of the major environmental factors which limits the survival of the organisms. In the present study, the biokinetic range of temperature for the prawn *Metapenaeus monoceros* was determined. It was found that these prawns

could tolerate a temperature range of 10 to 39°C. The thermal resistance of the prawns changed with acclimation levels. The rate of acclimation was slow at the upper lethal temperature. The thermal tolerance of the prawn was 721 units (square degrees in Celcius Scale).

EXPERIMENTS ON THE SALINITY TOLERANCE OF THE LARVAE OF *MACROBRACHIUM IDELLA* (HILGENDORF)

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Zoea I to X stages of *Macrobrachium idella* were reared separately in freshwater and in different salinities at 5, 10, 15, 20, 30 and 35%. Experiments showed that all the zoeal stages neither moulted nor survied when reared in freshwater, although the first zoea survived in this medium upto a maximum of 3 days after hatching. While the first 3 larval stages tolerated a salinity range of 10-35‰, it was found that, as the larvae advanced in development the upper tolerance limit gradually lowered to 25‰. The normal development of the larvae through different stages was recorded in the salinity range of 10-25‰, however the optimum survival was at 15‰.

DISEASE INFESTATIONS IN CULTURE OF THE FRESHWATER PRAWN *MACROBRACHIUM MALCOLSONII* (H. MILNE EDWARDS) A CASE STUDY

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The freshwater prawn culture, at least at present, is not reported to suffer much from disease problems unlike, the aquaculture of other organisms. But with the freshwater prawn culture gaining increasing popularity and with the emphasis on high production-oriented intensive culture practices, practically disease-free state of prawn culture may not last long. Also whatever information available on diseases is restricted to a single species *Macrobrachium rosenbergii* (de Man) which is the only dominating species cultured. As such, the urgent need for continued studies on diseases and their control in prawn culture, was realised when several infestations were encountered while developing mass culture technology on *M. malcolmsonii*, another potential species for culture with a promising future.

The present paper deals with various disease infestations, such as fungal, bacterial and other miscellaneous ones like black-spot besides algal epibionts, and the measures tried for their control, while working on the culture of *M. malcolmsonii*. Possible preventive measures are also suggested.

AN APPROACH TO TRANSFER OF TECHNOLOGY ON PRAWN FARMING

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Tamil Nadu has an estimated brakishwater area of 80,000 ha of which 27,000 ha can be immediately utilised for culture. In addition, about 1.2 lakh ha of brackishwater in the form of disused salt pans and low-lying areas are also available for culture purposes. Utilisation of these resources requires huge investment which has to be generated from the private, public and joint sectors. In this context the transfer of technology to the interested persons is an urgent need of the day. To achieve the above objective, Government of Tamil Nadu has sanctioned a scheme of training and extension services in prawn culture to interested private entrepreneurs. The present paper deals with the methods of training and other follow up extension measures taken up by the Department.

A CASE STUDY OF EXTENSION TECHNIQUE IN PRAWN FARMING

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A case study was conducted about the effectiveness of training given by the Fisheries Staff Training Institute on prawn culture. A farmer at Nagore, Tamil Nadu has been periodically taking advice from the institute. The details of operations and informatio ns on site selection, pond construction, fertilizer, feed, finance and managem ent are critically analysed. The paper also details the follow up measures adopted.

EXPERIMENTS ON THE PACKING AND TRANSPORTATION OF PRAWN AND MULLET SEEDS

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A series of field and laboratory experiments were conducted to study the behaviour and survival rate of prawn and mullet seeds under different conditions of packing for transportation and to know the effects of long travel on them. Selection of suitable containers for packing the optimum density of seeds per litre of water while packing and transportation and the influence of aeration, oxygenation, feeding, oxygen depletion and temperature on the survival of seeds were the aspects considered during the present investigations. Seeds of *Penaeus indicus* of 20-30 mm and mullet fry of 12-20 mm size

were collected and used for the experiments. Mortality rate above 15% recorded during the experiments, was considered as failure.

The results indicated that the earthernwares were the best suited for long time storing of seeds (more than two days) without appreciable mortality and 50 seeds per litre of water could be the optimum number for packing and transportation under unoxygenated condition. The minimum level of dissolved oxygen for the healthy maintenance of *P. indicus* seeds in captivity was found to be above 2.2 ml/1 and their maximum level of temperature tolerance was 38°C. Supply of feed to the seeds in captivity did not give satisfactory results. The observations and results of the experiments are discussed in this paper.

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