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# mbai-mecos 3

## Book of Abstracts

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**Marine Ecosystems**

**Challenges & Opportunities**

8-10 January 2020, Kochi

MBAI

Marine Biological Association of India

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**Marine Ecosystem**
**Challenges & Opportunities (MECOS 3)**

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# Foreword

The Marine Biological Association of India (MBAI), established in 1958, is proud to gear up for MECOS3, the third symposium on Marine Ecosystems- Challenges and Opportunities during 7-10 January, 2020. The MBAI besides organising MECOS1 (2009) and MECOS2 (2014) has inculcated active interest and participation among its members by handling several national and international symposia/seminars, since its formation. The MBAI has 794 life members and 20 institutional members. The mandate of the MBAI is promotion of scientific research in the field of marine biology and allied sciences. The much awaited MECOS3 has 357 abstracts covering seven focal themes:

**Theme 1:** Fisheries and ecosystem sustainability
(89 abstracts – 14 Express oral presentations & 75 Digital screen presentations)

**Theme 2:** Responsible aquaculture production systems
(51 abstracts – 15 Express oral presentations & 36 Digital screen presentations)

**Theme 3:** Marine biodiversity assessments and valuation
(76 abstracts–25 Express oral presentations & 51 Digital screen presentations)

**Theme 4:** Climate change and meeting SDG-14 goals
(46 abstracts–18 Express oral presentations & 28 Digital screen presentations)

**Theme 5:** Marine biotechnology and bio-marine products
(62 abstracts–15 Express oral presentations & 47 Digital screen presentations)

**Theme 6:** Livelihood, economics and trade
(23 abstracts–15 Express oral presentations & 8 Digital screen presentations)

**Theme 7:** Green harvest and post-harvest technologies
(10 abstracts–10 Express oral presentations)

Globally renowned scientists and researchers are to lead each session/focal theme, sharing their expertise and knowledge with the audience: Sahar Fahmy Mehanna – Challenges faced by Small Scale fisheries, John Kurien- Indian marine fisheries: Plausible Pathways into the future, Yugraj Singh Yadava-Development of value chain in south India, Edouard Le Bart- Eco-labelling, K.K.Vijayan- Ecosystem approach to brackishwater aquaculture, G.Gopakumar- Marine finfish breeding using RAS, K.K.Salin- Ecofriendly and energy efficient aquaculture systems in Asia, Nguyen quang Huy- Recent developments in marine fish farming in Vietnam, K.Ambasankar- indigenous microfeeds for Indian aquaculture, Vijay Anand- Fish feed industry in India, E.Vivekanandan- Is Wild life (protection) act, 1972 effective in conservation of marine species in India,Rajeev Raghavan-Towards zero extinction: the barometer of India's marine life, Kartik Sankar- The role of citizen science in marine conservation, P. K.Krishnakumar- Role of blue carbon habitats in mitigating and adapting to climate change, Sanjay Chaturvedi- Meeting SDG 14 goals in Indian context, K.V.Rajendran-

New paradigms in invertebrate immunity, Kajal Chakraborty-Marine natural products, N.K.Sanil- Tackling diseases in farmed aquatic animals, N.Venugopalan- Implementing the SSF guidelines, V.Vivekanandan- Role of fisheries societies in fisheries management, Pranab Mukhopadhyay- Marine ecosystems-are economists just bystanders?, Petri Suuronen- New developments in green fishing technologies and C.N.Ravisankar- Recent trends in fish processing.

Noteworthy articles by the presenters in the seven focal themes cover wide areas of marine research- stock status of fishery resources, modelling in fisheries, fishery biology, jellyfish fishery, elasmobranch fishery, age and growth studies, diet and trophic interactions, growth studies on prioritised mariculture species, reproduction and larval fish management, feed technology, brood stock development, copepod culture, aquaculture, cage farming, taxonomy and systematics of marine organisms, diversity and distribution of marine living resources, valuation of ecosystem services, microplastics in coastal waters, Island ecosystems, mangrove biodiversity, sponge diversity, plankton diversity, elasmobranch species diversity, carbon sequestration potential of mangrove ecosystem, reef resilience studies, bioremediation, fisheries and climate change, carbon foot print, water quality, fish disease, histopathology, Jellyfish first aid kit, mitochondrial genome, aquaculture drugs, bioactive compounds, pharmaceutical studies, anti-inflammatory compounds from marine organisms, bioprospecting, parasitic disease, nutritional studies, impact of cyclone on marine fisheries, adoption of Mariculture technologies, Kadal osai – A communication network and gender and fisheries sector.

It is worthy to note the response of students from various research organisations and universities, who contributed to MECOS3. The symposium is remarkable as a green symposium with low carbon footprint–only online book of abstracts, mobile app instead of printed program guide, only digital presentations, no single use plastics in catering and only PDF of certificate of participation/presentation.

It is appropriate to pay homage to Dr.E.G.Silas, Former Director, CMFRI and Former President, MBAI; Prof. (Dr.) N.R.Menon, Former Co-Chairman, Board of Directors of Nansen Environmental Research Centre – India, Former Dean–Faculty of Climate Variability and Aquatic Ecosystem, KUFOS and Former Vice-President, MBAI and to Dr.P.S.B.R.James, Former Director, CMFRI and Former President, MBAI for their excellent support and contributions to Marine Biological Association of India.

The MBAI thank all those who contributed towards MECOS3. We look forward to your active deliberations/discussions during the symposium which will provide momentum towards conserving and sustainably using the marine resources and the oceans.

06.01.2020

Editors

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Theme 1

# Fisheries and ecosystem sustainability

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# Challenges faced by the small scale fisheries and its sustainable development

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Fish and fish products account for almost 20 percent of global animal-based protein consumption and they are also critical sources of micronutrients necessary for human health. Small-scale fisheries (SSF) critically contribute to food security, sustainable livelihoods, nutrition and poverty alleviation especially in developing countries. SSF in coastal and inland communities across the world are a major component of the world's food system providing food and livelihoods for hundreds of millions of people around the world. These traditional fishing communities found predominately in Asia and, to a lesser extent, Africa, account for more than half of total global fisheries catches and employ more than 90 percent of the world's capture fishers and fishworkers, of whom almost half are women (World Bank, 2012). Despite the contribution of SSF to feeding a growing population in both the developed and developing world, the fisheries are often ignored in states' policy making, in part because their value has been poorly measured. Despite this significant contribution, the issues constraining the sustainable development of small-scale fisheries remain poorly discussed. Yet, these fisheries as social-ecological systems are poorly understood due to the structure and dynamics of harvesting resources in a complex fishing process, which involves subsistence, recreational and commercial users as well as interaction with a governance subsystem influenced by cultural, social and political factors (Defeo *et al.,* 2016).

Small-scale fisheries are facing a number of challenges, including external threats such as invasive species, infrastructure development, eutrophication, coastal pollution and distal drivers (e.g. markets, governance and human migration to the coast), overfishing, climate change and ocean grabbing that deprives small-scale fishers of resources and undermines their historical access to areas of the sea. Also, one of the biggest problems for both large and small-scale fisheries around the globe is by-catch (fish and other marine organisms caught when the fishers are targeting something else). Most of the endangered and threatened species like sea turtles and dolphins are caught as by-catch.

These threats to small-scale fisheries, coupled with their lack of political voice in many cases could affect global food supplies and have damaged both productivity and ecosystem health, leading in several cases to collapses of fisheries and even to extirpations of certain locally exploited fish populations. For these reasons, the partners on the new global study are particularly focused on the role of small-scale fisheries in helping to meet the first two of the 17 United Nations Sustainable Development Goals (SDGs): to end poverty and hunger.

SSF require distinct management solutions and therefore cannot be lumped together with industrial fisheries in management and governance frameworks (Defeo and Castilla, 2005; McClanahan and Castilla, 2007). The Voluntary Guidelines for Securing Sustainable Small-Scale Fisheries in the Context of Food Security and Poverty Eradication (SSF Guidelines; FAO, 2015), endorsed in 2014 at the 31st Session of the FAO Committee on Fisheries (COFI), represent an important step towards managing small-scale fisheries as social-ecological systems, one which acknowledges fisheries management as involving more than just the management of fish stocks. The SSF Guidelines focus on managing fisheries in ways that improve the livelihoods of small-scale fishers, address equity and diversity issues in fisheries (e.g. gender participation) and ensure environmental sustainability (Jentoft *et al.,* 2017a). Importantly, the Guidelines are grounded in a commitment to secure the human rights of small-scale fishers, their families and communities, which places them firmly in the context of an approach to fisheries management based on social-ecological systems. Kearney (2007) has identified five key components of human rights in the context of small-scale fisheries; namely, the right to: (1) fish for food; (2) fish to earn a living; (3) healthy families, communities and cultures; (4) a healthy environment; and (5) participate in fisheries decision-making.

Small-scale fisheries (SSF) are an important contributor to the Egypt's fish production; accounting to around 83% of total landed catches with a fleet comprises more than 90% of the Egyptian fishing fleet (GAFRD, 2017). Most small-scale fishers have historically worked under an informal and marginal system, which has prevented their social inclusion, access to credits and social security and their active participation in the management process.

Despite the critical contribution of SSF to nutrition, food security, national economies and poverty alleviation, there are many challenges faced by this important sector and its related communities. Overfishing, habitat degradation and land-based activities are the key challenges facing the SSF communities in Egypt. With the serious decline in different fish stocks in the Egyptian fisheries, the government started to pay attention to how to support and improve the small-scale fisheries. In this presentation, we will discuss the importance of SSF and the main challenges facing this important sector as well as the global efforts to sustain and develop it. Also, we will give an example for SSF in Egypt, the northern Egyptian lakes, for their economic importance as they provide up to 77% of the lakes production in Egypt and they support the Mediterranean fisheries as they act as a nursery ground for many fish species inhabiting the Mediterranean Sea. We will throw the light on the current situation of the lakes' fisheries, the key challenges facing the SSF and their communities working and living in and around them as well as the efforts exerted by the Egyptian government to support those communities, to improve their livelihoods and to invest in this sector to enhance its productivity.

# Indian Marine Fisheries: Plausible Pathways into the Future

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Predicting the future is tricky business. And in a fuzzy and fluid realm like marine fisheries it is an intractable task.

The experience of the past teaches fishworkers, fishery scientists, fishery bureaucrats, civil society and political society members one truth about marine fisheries in the future: we cannot influence and manage the actions of fish, we can only influence and manage people's actions.

Therefore, plausible pathways into the future will depend on the actions that people in marine fisheries decide to take and the influence which can be brought to influence their behaviour.

The action of fishworkers are conditioned by livelihood concerns. Fishery investors seek profit and make investments accordingly. Marine biologists seek to study marine eco-systems and behaviour of living resources for academic purposes. Fishery policy makers seek to create governance conditions in which the marine fishery sector as a whole can function optimally. The coastal politicians seek votes and wish to work for the welfare of coastal communities. Civil society activists seek to influence actions of all the various actors in the fisheries realm.

The combination of the actions of all the above can result in a variety of plausible pathways into which marine fisheries in India will move into the future.

Having been a development practitioner for over four decades valorising small-scale fisheries at local, state, national and international realms, this keynote talk will attempt two tasks:

Firstly, highlight why we should move to a future with small-scale fisheries as the backbone of marine fisheries development and management in India.

Secondly, propose some important measures to be taken to influence and manage people's actions to achieve this objective.

# Development of Tuna Value Chain in South India

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Tuna is estimated to contribute at least US$ 42 billion in end value to global economy each year, making it the most valuable seafood commodity with high value and large markets. In 2015, the global tuna catch was estimated at 4.8 million metric tons (mmt). The Indian Ocean (IO) has large and valuable stocks and in 2014, 4.1 mmt of the main species (albacore-*T. alalunga*; bigeye tuna-*T. obesus*; yellowfin tuna-*T. albacares* and skipjack tuna-*Katsuwonus pelamis)* were caught, valued at over US$ 8.7 billion at the final point of sale. The estimated potential economic value of both oceanic and coastal tunas in the IO is estimated at US$ 2.06 billion per year. The estimated asset value has been pegged at US$ 26 billion, to provide an 8 percent return. However, to realise these values, there are certain essential pre-requisites such as (i) effective supply and value chain; (ii) well-managed fisheries; (iii) quality fish traded to relevant markets (domestic or international); (iv) institutional capacity and human capacity.

In 2018, the potential of tuna and tuna-like species in Exclusive Economic Zone (EEZ) of India was estimated at 230,832 metric tons (mt), with the potential of the two principal tuna species- yellowfin and skipjack pegged at 83,500 mt and 99,500 mt respectively. The landings of these two species in the same year were estimated at 37,388 and 36,387 mt respectively, suggesting that their catches could be increased, albeit on a sustainable basis.

In India, tunas are harvested both by larger multi-day fishing vessels operating in the EEZ and small-scale fishing operations, mostly targeting the coastal tunas. However, as gill net is the major fishing gear used for catching tuna in India, the quality of the landed fish is poor and, therefore, compared to other major tuna-fishing countries in the region, namely Maldives and Sri Lanka, India has realised 203 percent and 357 percent less, respectively, per tonne of fresh or chilled yellowfin tuna export on an average during 2000[1]-17.

Tuna has unique characteristics and requires special handling from the first point of capture to table. Improper handling can directly impact the quality of tuna meat texture, including smell and taste. Proper tuna handling on-board and rapid chilling can produce reliably high quality tuna product. There is also a need to provide technical information on how to deliver high quality tuna at the landing site, including step- by- step handling of the harvest and chilling recommendations that will prolong the shelf-life and freshness of the fish. Thus, there is potential to capitalise on tuna resources, through careful analysis and planning, management and investment.

To address these requirements, the Bay of Bengal Programme Inter-Governmental Organisation (BOBP-IGO) through a Global Environment Facility/World Bank grant implemented the 'Ocean Partnerships for Sustainable Fisheries and Biodiversity Conservation - Models for Innovation and Reform" (OPP) Project' during 2015-2018. Two pilots were selected under the Project, one in Vaithikuppam village in the Union Territory of Puducherry and the other in Jaleripalam village under Pudimadaka Panchayat in Visakhapatnam district of Andhra Pradesh. The larger objective of the two pilots were to establish profitable and viable yellowfin tuna processing enterprises that will help to strengthen the yellowfin tuna value chain and contribute to the local and national economies through employment opportunities, generation of economic profits and tax revenue. In both the pilots, focus was on the following:

- *Creating win-win partnerships between fish harvesters and small-time fish processors;*
- *Moving from volume to value;*
- *Training and capacity building at all levels;*
- *Providing one-time assistance to harvesters and processor in improving/upgrading their on-board storage and processing facility; and*
- *Connecting processors to the market.*

The work on these pilots started in mid-2017 and completed by the third quarter of 2018. Both the pilots have established well and have expanded their market reach, catering to supermarkets and up-market restaurants in major cities like Visakhapatnam, Puducherry, Chennai and Bengaluru. The harvesters are catching only as much yellowfin tuna that they can bring back to the shore in good condition and in the process are getting better price from the processors, an increase ranging from 50-75 percent as compared to the earlier price.

Having met the initial requirements of the 'triple bottom line (environmental, social & financial), the pilots are now being replicated in a couple of other locations in South India to ensure safe and assured supply of seafood to markets, employment at a local level to help stabilize and support rural and urban communities and incentives to manage the underpinning fisheries on a productive and sustainable basis.

# Eco labelling – A Global review of Marine Stewardship Council's Blue Label Certification

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Marine Stewardship Council (MSC) have certified 361 certified fisheries which forms 11.6 million tonnes of certified catch (15% of Global catch) & 109 fisheries in assessment. Between 2016 and 2018, MSC certified fisheries have made 288 improvements to ensure best practice, including 143 to minimise their environmental impact, 75 to ensure the sustainability of fish stocks, 70 to strengthen fisheries management, 16 improvements benefitted marine mammals, 33 improvements benefitted sharks and rays, 9 improvements benefitted marine reptiles, 44 improvements benefitted habitats & 36 improvements benefitted seabirds. Sustainability performance of MSC certified fisheries around the world over past 20 years is appraised. The appraisal covers impact on global reach, evolution of the fisheries standard, improvements on water, sustainable fish stocks, traceable supply chains, improving access, market and consumer demand, developing world scenario & the future of sustainable seafood

# Status of marine fishery resources in southwest coast of India by modelling stock biomass dynamics in a multi-gear fishery

Sathianandan T. V.*, Mohamed K. S., Jayasankar J., Somy Kuriakose, Mini K. G., Eldho Varghese, Zacharia P. U., Prathibha Rohit, Maheswarudu G., Vijayakumaran K., Kaladharan P., Najmudeen T. M., Mohamed Koya K., Sivadas M., Shoba Joe Kizhakudan, Geetha Sasikumar, Ganga U., Sujitha Thomas, Lakshmi Pillai S., Grinson George, Vinay Kumar Vase, Vivekanand Bharti, Sreepriya V., Alphonsa Joseph and Deepthi A.

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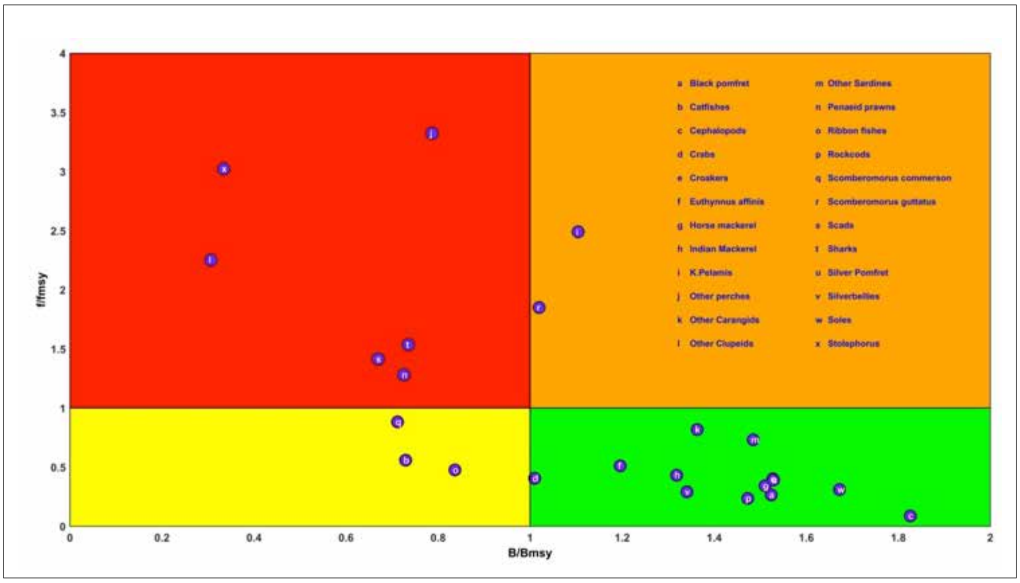
The marine fisheries sector in India contribute significantly to the food and nutritional requirements of its people and support livelihood of nearly four million fisher population in addition to foreign exchange earnings through export. Nearly 33 % of the marine fish production is from the southwest coast comprising the states of Kerala, Karnataka and Goa which is only 16.4% of the total coastline. Harvest of the marine fishery resources requires proper control through appropriate management measures for sustainability of the resources. The most commonly used management reference point, maximum sustainable yield (MSY), is derived here for all the important marine fishery resources in these states considering the multi-gear fishery and adopting suitable biomass dynamic modelling approach with time series data on gear wise fish catch and fishing effort as input sourced from the National Marine Fishery Resources Data Centre (NMFDC) of ICAR-Central Marine Fisheries Research Institute.

In the modelling approach, the multi-gear situation was handled by incorporating a set




Kobe plot showing stock status of 24 resources examined in the fishery in Kerala of parameters into the observation equation of the biomass dynamics model and all the model parameters, MSY, biomass at MSY level and fishing effort at MSY were estimated for 24 resources in Kerala, 26 resources in Karnataka and 11 resources in Goa. Kobe plots were prepared for each state to see the current status of different marine fishery resources in these states using information on ratios of current levels of fishing effort and biomass in relation to the optimum levels of fishing effort and biomass. In the Kobe plot for Kerala, out of the 24 resources examined 13 were falling in green category (both biomass and fishing effort satisfy conditions for sustainability), 3 in yellow, 6 in red and 2 in orange. In Karantaka, out of the 26 resources modelled 9 were green, 5 were yellow, 9 were red and 3 were orange. In the case of Goa, 5 out the 11 resources were green, 5 yellow and 1 red.

# GIS based management of trawl fishery along Visakhapatnam coast

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Investigations on the trawl fishery resources, their spatio-temporal distribution and abundance along Visakhapatnam were carried out during 2015-17. Experimental trawling off Visakhapatnam (Lat 17.3-18.3N, Long 83.42-83.6E) was conducted using 29.4 m bottom trawl with 20 mm cod-end mesh. Thematic maps of trawl fishery resources and their spatial distribution were prepared using QGIS software.

Considering the data for two-year period (2015-16 and 2016-17), the mean total catch and catch per hour (CPH) was 30.4 kg/haul and 19.4 kg/h respectively. Depth of operation ranged from 20 to 70 m at a trawling speed of 2.0-3.0 knots and the distance from shore ranged from 10-30 km. Analysis of data from 40 hauls revealed that maximum catch was recorded beyond 30 m depth. Mean monthly fish catch, by-catch and CPH was 121.5 kg, 30.7 kg and 19.4 kg respectively.

Commercial catch consisted of 137 species from 53 families (15 orders) of finfishes and shellfishes. Among these, *Lepturacanthus savala* dominated the commercial fish catch with 6.6% contribution followed by *Upeneus vittatus* (6.5%) and *Pennahia anea* (6.3%). Among these, *L. savala* was dominant in December (1.3%) and *U. vittatus* and *P. anea* in June (1.4%) and September (0.9%) respectively. *T. lepturus* catch was highest in July (1.5%) followed by August (1.2%).

Assessment of monthly variation in juvenile catch revealed that the highest percentage of juveniles and mature fishes in terms of numbers were recorded in June (15.1%) and March (17.3%) respectively. Maximum percentage of mature fishes in terms of numbers were recorded for *Saurida undosquamis* (15.2%) followed by *P. anea* (13.9%) and *L. savala* (12.1%). Juveniles and mature fishes were abundant at the end of pre-monsoon and beginning of the monsoon season. Restriction on fishing of juveniles and spawners during this period would help to avoid biological overfishing and resource management.

In all, juveniles of 46 fish species belonging to 22 families (9 orders) were landed by trawlers. Juvenile catch (in terms of numbers) varied from 1-14 % of the total catch. The percentage of juvenile catch was highest for *Eubleekeria splendens* (14%) followed by *Leiognathus equulus* (8.4%) and *Secutor insidiator* (7.2%). Among the all-mature fishes *S. undosquamis* was dominant followed by *P. macropthalmus* and *L. savala*. Maximum concentration of juveniles was recorded in 30-50m depth range.

Highest percentage of bycatch landed was in January followed by February and June and the percentage varied from 13.9 to 29.0%. Average percentage of bycatch per month was recorded as 22%. Ponyfishes, Apogon sp, ribbonfishes, squilla and crabs were the major contributors to the bycatch. In all, 168 species belonging to 63 families contributed to low value bycatch excluding the shells and bivalves.

Alpha diversity of trawl catch was more in the first quarter compared with second quarter. Alpha diversity increased in the third quarter (Jul-Sep) immediately after fishing ban. Margalef index estimated that alpha diversity of trawl catch increased at very fast rate after summer season.

# Gastropod fishery of South Tamil Nadu - an overview

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Gastropod production in India was comparatively insignificant in earlier times when compared to the other molluscan fishery resources. Ornamental molluscs is an emerging resource and has been received considerable attention due to its greater demand as ornamental shells for shell handicrafts and as meat for consumption. In this view, a study was attempted to document the gastropod fishery from the Southern coast of Tamil Nadu (Ramanathapuram, Thoothukudi, Tirunelveli and Kannyakumari Districts) from 2013 to 2018. The study revealed that the gastropod are mainly caught in different gears such as trawl net (bottom trawls), bottom set-gill net (crab net, lobster net and chank net) and skin diving using mechanised trawler, vallam, FRP and catamaran boat. Among the four districts, Ramanathapuram contributes the maximum gastropod production with an annual average catch of 951 tonnes of which trawl net contributes 94 % and the rest 6 % is from skin diving. The average annual catch of Thoothukudi was 311 tonnes; the major portion of the catch is by skin diving (59 %) followed by gill net (31 %) and trawl net (10 %). In Kannyakumari, the annual average catch is 296 tonnes of which trawl net was dominant gear contributing 82 % of the total catch and the rest is by gill nets. The annual average gastropod exploitation from Tirunelveli is 134 tonnes through gill net.

During the observation period in Ramanathapuram district, by skin diving *Lambis lambis* contributed 67 % followed by *Turbinella pyrum* (30 %) and *Chicoreus ramosus* (3 %). In trawler *Volegalea cochlidium* (8 %), *Chicoreus virgenius*, *Natica* spp., *Conus* spp and *Oliva* spp., (each 7%) are the major contributing group. In Thoothukudi district, the gastropod species composition in skin diving was *Turbinella pyrum*(14 % ), *Chicoreus ramosus* (56 %) and *Lambis lambis* (30 %); In gill net *(Turbinella pyrum* (42 %) and *Chicoreus ramosus* (58 %); In trawl net the major contributing group in the catch was *Babylonia zeylanica* (22 %), *Babylonia spirata* (18 %), *Xenophora corrugata* (15 %) and *Nassaria* spp. (10%). In Tirunelveli district, *Turbinella pyrum* was the maximum contributing species in the gastropod fishery.

The gastropods form a niche in the export industry and becoming highly priced objects in Indian and foreign markets and the fishery supports a huge number of the coastal population either directly or indirectly for making the ornaments and handicrafts from gastropods shells. In this study region, gastropods are mainly exploited for its shell and plays an important role in the commercial shell craft industry in Southern coast of India. From Thoothukudi District, the meat of *C. ramosus* exported to Thailand. Apart from the shell and meat, the dried operculum of gastropods is in immense demand in the international market. The operculum of gastropods have good market value ranging from Rs. 1,000 to 14,000 depends on the species and operculum powder is an important ingredient in fragrance making. In addition, from the Thoothukudi region the under sized and infested gastropod has been transported to Northern part of Tamil Nadu where the minced and powdered shell is used as an ingredient for the poultry feed.

# Contaminant bioaccumulation and human health as important parameters for future of sustainable fisheries - A case study for mercury

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Fish is an important source of nutrients and protein. They are especially excellent sources of omeaga-3 polyunsaturated fatty acids (PUFAs). However, at the same time, fish (including shellfish) are also known to bioaccumulate a suit of organic and inorganic contaminants and act as source for human exposure to these contaminants. Example contaminants include organic compounds such as persistent organic pollutants and the neurotoxin mercury (specifically methyl mercury). Here, I focus on mercury, which is now regulated under the global UN Minamata Convention for Mercury, for which India is a party. Fish intake is the main global exposure pathway for methyl mercury exposure. Climate change may also increase the bioaccumulation of mercury in fish and the subsequent human exposure to mercury.

India is among the top emitters of anthropogenic mercury to the atmosphere. Mercury emissions to the atmosphere in India have been estimated to be 156 tonnes in the year 2001, 234 tonnes in 2010 and projected to be 451 tonnes in 2020. Mercury pollution from India is expected to further increase in the future. However, at the same time, fish production and consumption in India is increasing at a tremendous pace. Therefore, it is likely that mercury in fish will become an important and prominent, topic in India in the near future both in the eyes of the public and the regulatory authorities.

Here, the presented work will summarize the current information on mercury contamination of fish produced in India, the international frameworks emerging for mercury monitoring and outlook for the future with respect to management of mercury exposure from fish consumption. For assessing the mercury content of fish in India, literature published since 1995 was searched in online indices Scopus, Google Scholar and Web of Science. Quality assurance and control protocols of the reviewed studies was evaluated before inclusion of their results. About, only, twenty studies have been identified so far (mercury seems far less studied in India than in other countries). First, reviewed concentrations of mercury in fish were checked with critical limits and screening values stipulated in India, the World Health Organization (WHO) and the United States Environmental Protection Agency (USEPA). Then, with respect to mercury policy, discussions and frameworks adopted in other countries and being discussed in the Minamata Convention for Mercury were reviewed.

From survey of mercury contents in Indian fish, it was found that many reported concentrations of total mercury in aquatic biota are above the screening value recommended by the USEPA, 0.3 μg/g.

Overall, the emerging pattern is that mercury contamination and exposure already is and becoming an even more, important topic in India. This can no longer be ignored by the relevant stakeholders and the policy of '*ignorance is bliss*' may not be sustainable. It is time for the scientific and industrial community to come together and preemptively devise a plan for proper monitoring of contaminants such as mercury in fish and a method of communication that help preserves public health while still encouraging fish consumption for all its benefits. Fish is good for health!

# Examining food web and trophic structure along Mumbai coastal water

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In the present study, trophic level of fishes from experimental trawl fishing on-board *MFV Narmada (IV)* along the Mumbai coastal waters were studied. During the study, species collected were identified up to species level. The concept of trophic level is particularly relevant in order to improve knowledge of the structure and the functioning of an ecosystem. To obtain a good picture of the food web, fish stomach content analyses and a bibliographic synthesis of the prey feeding ecology were carried out. The feeding link investigation enabled us to identify qualitatively and quantitatively the different preys consumed by each fish group studied, to distinguish the prey feeding on benthos from those feeding on surface feeder and to characterize the different nutritive pools at the base of the system. The present work shows that trophic positions are linked with the feeding ecology of fish species and vary according to individual size. Understanding the trophic level interactions among major link to sustain the trophic guilds of low trophic level marine fisheries determine productivity richness relationships will necessary in the order so that we can achieve a comprehensive understanding of the determinants of diversity. The trophic functioning of marine ecosystems is a key to improving the implementation of an ecosystem based fisheries management.

# Estimation of maximum sustainable yield for small and medium-sized croakers using surplus production model incorporating environmental effects from North-west coast of India

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Fishes of family Sciaenidae, popularly known as croakers forms a major fishery along the north-west coast of India. In general croakers can be divided into three major groups based on size. Large sized croakers of species belonging to the genus *Otolithoides* (Koth) and *Protonibea* (Ghol) are prized species in the region for their swim bladders. The fishery of these two resources in the region have showed signs of overexploitation viz. decreasing catch and mean length of the catch etc. Though, the two above mentioned species have attracted a lot of scientific attention, the medium and small sized croakers of genus *Pennahia, Otolithes, Nibea* and *Johnius* too have faced the wrath of increasing fishing intensity. These medium and small sized croakers are mostly harvested by trawlers, multiday dolnetters (MDOL) and outboard gillnetters (OBGN). They together accounted for more than 90% of the total catch of small and medium sized croakers over a period of 2007-18. The study is conducted to estimate the gear wise MSY for the small and medium sized croakers as the area of fishing (vertical and horizontal) are different for these gears. In addition to the fishing, the environmental factors are known to affect the biomass and realized CPUE for the resources. Hence a surplus production model including environmental effects was attempted. The conventional fox model and derived fox model with non-linear effect of environmental parameters were attempted with two environmental variables annual chlorophyll a (Chla) and sea surface temperature (SST). The incorporation of Chla in the model improves the model fit by nearly 10 % in case of MDOL whereas the SST improves the model output of OBGN by nearly 11%. No improvements in model fit were observed in case of trawlers. The cumulative MSY estimated by the opting best fitted models for each gear were almost 49,000 t which was marginally higher than the estimates by conventional fox model. It is concluded that, though environmental factors are known to affect the abundance of the species in an area, but in present case the fishing effort has the major bearing on the stock.

# Variability in size-fractionated chlorophyll-a concentration across the Atlantic Ocean

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One of the aims of the Atlantic Meridional Transect (AMT) programme was to quantify carbon cycling in the Atlantic Ocean. Phytoplankton biomass, measured by its proxy chlorophyll-a is a critical component of this cycle. Phytoplankton communities comprised of various size classes such as micro-plankton (>10 µm), nano-plankton (2-10 µm) and pico-plankton (0.7-2 µm). Each of these size classes contribute an important role in biogeochemical cycling to support fisheries, regulate the amount $CO_2$ from atmosphere to the ocean, in the recycling of carbon in the photic zone and accumulation of carbon in the sea floor. During AMT 29, we measured the size-fractionated phytoplankton chlorophyll-a at various depths across the transect in the Atlantic Ocean (Welschmeyer, 1994). The total chlorophyll concentration in the Atlantic waters varied from 0.083- 1.84 mg $m^{-3}$ in the surface ocean and 0.297- 2.005 mg $m^{-3}$ at the Deep Chlorophyll Maximum (DCM). Chl-a concentration from micro-plankton varied from 0.0054-0.761 mg $m^{-3}$, nano-plankton varied from 0.118-0.069 mg $m^{-3}$ and pico-plankton varied from 0.0057-0.647 mg $m^{-3}$ in the surface waters and 0.0037-1.362 mg/$m^3$ and 0.0097-0.354 and 0.1219-1.020 mg $m^{-3}$, respectively in the DCM. Total chl-a was the maximum in the western channel of North Atlantic and in the Argentine Basin of South Atlantic. Micro-plankton was the most abundant group at western channel whereas the Argentinian Basin was dominated by pico-plankton. Waters near the equator were dominated by picoplankton as evidenced from the high chl-a values, which could be due to the influence of equatorial upwelling. Nano-plankton was abundant in all regions, with maximum being recorded at Bay of Biscay. Recently size fractionated phytoplankton models have been developed from remote sensing ocean colour data to estimate size-fractionated chlorophyll-a. Results obtained by way of the present in situ measurements would be used to validate remote sensing models of size-fractionated Chl-a in the Atlantic Ocean.

# Assessment of the trend and status in dolnet fishery along the Gujarat coast of India using holistic model

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The Dolnet fishing along the northwest coast of India is a traditional one and unique in many ways. Gujarat is the lead maritime state of the country in dolnet fishing. The Dolnets in the region are operated by both the mechanized and motorized dolnetters. The overall length (OAL) of dolnetter's range between 12 and 14 m and powered with an engine of 85-110 HP. Dolnetters contributed significantly to the total marine fish landings of Gujarat during 2018 with a contribution of 2.9 lakh t (37.20%). The non-penaeid prawns (0.72 lakh t) were the major resource in the dolnet during the study period, followed by bombayduck (0.56 lakh t), croakers (10.60 lakh t), ribbonfish (0.096 lakh t), penaeid prawns (0.091 lakh t), catfishes (0.088 lakh t) and golden grenadier(0.077 lakh t). A major portion of the dolnet catch is utilized for drying (non-penaeid prawns, bomdayduck, golden grenadier and small sized ribbonfish). A large percentage of the dried fishes are used for preparation of fish meal and lower volume for domestic consumption. The catch and effort data (in fishing hours) for the dolnet fishing during 2004-2018 was used as an input in the Schaefer surplus production model. The maximum catch was recorded during 2018 (2.90 lakh t) and minimum during 2004 (0.84 lakh t). Highest fishing effort (hrs) was recorded in 2017 (43.53 lakh hrs) and the lowest during 2013 (15.81 lakh hrs). MSY was estimated at 2.775 lakh t for the State which is marginally higher than the average catch (2.773 lakh t) of last three years. Dolnet is a passive gear and fishing mostly depends on the current movement restricting the option of shift in fishing grounds. Therefore the only management option left with is the control over the mesh size of the gear and number of fishing units. The present investigations infer that the exploitation limit can be fixed to the estimated MSY and more investigations on catch composition and mean size of the individual resources need to be done to understand the health status of individual fish stocks and also to frame management strategies for the long-term sustainability of the fishery.

# Pearl oyster stock rebuilding: A case study of Gulf of Kachchh

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Gulf of Kachchh (GoK) situated on western coast of Indian peninsula is well known for its diversified floral and faunal diversity and industrial establishment at its northern and southern shore. The GoK is also one of the known fishing ground for pearl oyster population in India. In India, the recorded species of *Pintada* genus for their gem quality pearl includes *Pinctada imbricata P. fucata, P. margaritifera, P. chemnitzi, P. atropurpurea, P. anomioides* and *P. sugillata. Pteria penguin* is also known for its quality pearl production. In Gujarat pearl oyster population is mainly constituted by *P. imbricata fucata*. The detailed study of exploitation and status of pearl oyster were carried out by James Hornell along GoK. During 1913 to 1967 pearl fishery were carried out by fisheries department of Navanagar State and Government of Gujarat. After 1966-67 pearl fishery were stopped due to depletion of pearl oyster population. During 1992-93, pearl oyster population were depleted to 6-17 numbers/km$^2$.

In order to restore the pearl oyster population, Fisheries Research Station, Junagadh Agricultural University, Sikka had produced 2740.556 lakh pearl oyster seed during 2009 to 2019 and among them 1307.742 lakh pearl oyster seed (Veliger stage to Juvenile stage) were released at different islands and reefs in Gulf of Kachchh.

The continuous effort to establish the pearl oyster population in Gulf of Kachchh now shows its positive results despite continuous illegal hunting, anthropogenic activities, pollution and global warming. The recent survey conducted by FRS, JAU, Sikka along Sikka coast confirms its population as higher as 85 number in a 2500 m long transect of 1 m width during 2019 while at Kalubhar the pearl oyster population was 22 in a 1500 mtr long transect of 1 mtr width in 2018. At Goose island pearl oyster density was recorded 12 in 1900 m long* transect of 1 mt width transect. The average size of the population in wild ranged between 4.3 cm to 8.2 cm Hinge length, 4.4 cm to 9.5 cm DVM and 10 gm to 160 gm weight. Pearl oyster were released into their natural ecosystem like sandy rocky substratum, intertidal region having tide pools, coral and other vegetation.

# Experimental validation of periodicity of increment formation in the Statolith of bigfin reef squid *Sepioteuthis lessoniana* (Cephalopoda: Lolignidae) from tropical Indian waters

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*Sepioteuthis lessoniana* (Lesson, 1830) is a neritic squid that inhabits coral, rocky reefs, seaweed and seagrass beds of the Indo-Pacific region. Increment validation or the periodicity of increment formation in squid statolith is fundamental for age determination, longevity estimation and life history traits, hence it is critical for fishery management and species conservation. Although studies have established one-increment-per-day hypothesis in neritic squids, it has never been validated for tropical Indian Seas. Squids are the dominant component of fauna in the Indian waters, hence an investigation on the statolith increment formation was undertaken for *S. lessoniana*, as a representative of Loliginid squids.

Egg masses of the bigfin reef squid were collected from Vethalai, Mandapam, southeast coast of India at a depth of 3m on 8th February 2019 by SCUBA divers. A single egg cluster contained 182 eggs with a hatching success of 95 % (172) in the laboratory. Hatching occurred at early morning hours from 2 to 5 AM. The planktonic hatchlings ranged between 3.9 and 5.49 mm (average 4.98 mm) in dorsal mantle length. They began to feed after 2-4 hours post hatching. The hatchlings were fed with live crustaceans (*Acetes* sp.) collected from wild, adult *Artemia* and hatchlings of Silver pompano (*Trachinotus blochii*) (1-2 mm). The paralarvae were maintained in captivity for 5 days within the tank. A total of 10 hatchlings were sacrificed each day for 5 days.

The size of the hatchling statolith (total statolith length) ranged from 318 to 418 μm (mean=360 μm). Hatchling statoliths had well-developed dome, wings and rostrum (Fig.1). Increments formed during embryonic development observed were 9-14 numbers (mean=12) in the nuclear region. First solid increment was observed one day after hatching. It was observed that most of the increment counts (82%) were consistent with the actual age of the squids post-hatching, though 18% of statolith counts were 1-2 (increments) days older than the actual age of the squid. The

Table.1 Relationship between age and number of increments in the statolith of *S. lessoniana* from tropical Indian waters under laboratory conditions.

| Days | n | Avg. DML(mm) | Increment (range) | Agreement (%) |
|---|---|---|---|---|
| 0 | 10 | 4.987 | 0(0-1) | 80 |
| 1 | 10 | 5.226 | 1(1-2) | 80 |
| 2 | 10 | 5.469 | 2(2-3) | 90 |
| 3 | 10 | 5.614 | 3(3-4) | 90 |
| 4 | 10 | 5.69 | 4(4-5) | 80 |
| 5 | 10 | 5.834 | 5(5-7) | 70 |

growth rate of the early stages ranges from 0.07 to 0.24 mm DML/day. The validation data presented here confirms the one day-one ring hypothesis in bigfin reef squid and possibly of similar increment formation in other tropical squids from Indian waters. However, the existing data are still modest and validation of increment formation of full lifecycle for the species continues to be a priority.

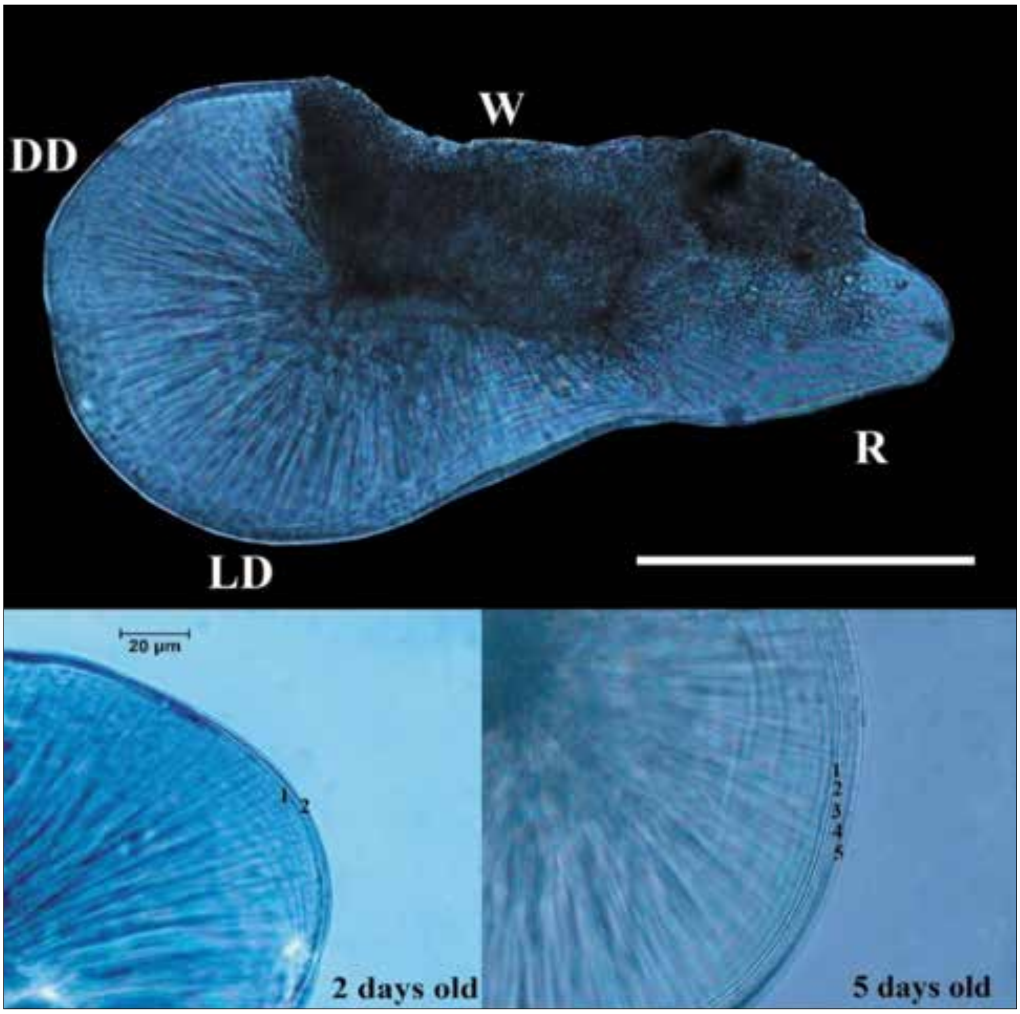


Fig.1. (a) Statolith of newly hatched *Sepioteuthis lessoniana*, DD =dorsal dome, LD=lateral dome, R =Rostrum and W=wing, (b) statolith micrograph of two days old squid with two increments and (c) five days old with five increments.

# Fishery, biology and stock status of Bombay duck, *Harpadon nehereus* (Hamilton, 1822) (Harpadontinae) caught from north eastern Arabian Sea

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Bombay duck, *Harpadon nehereus* (Hamilton, 1822) is a major contributor to the fishery of northern Arabian Sea of Indian EEZ. Fishery, biology and stock assessment of *Harpadon nehereus* from Maharashtra waters was studied from 2014-2018. The catch data from 1950 -2018 shows *Harpadon* fishery landing to all India catch ranged between 1.16-19%. All India highest annual catch was reported as 145,115t in 2017 and the annual average catch was 125,167 tonnes in the study period. In Maharashtra the highest catch was reported during 1991 with 48,022 tonnes. Gearwise contribution to the Bombay duck fishery landings shows that the dolnetters (73%) was the highest contributor followed by trawlers (26%). Fishes having the size range 95-385 mm contributed to the fishery. The sex ratio was 1:1.54. Length at maturity was estimated at 207 mm TL. Mature ovaries contained ova of all stages indicating the species is a continuous spawner. It was observed that crustaceans (77.7%) were the major prey item followed by teleosts (20.8%). Feeding strategy analysis of bombayduck showed that the fish doesn't have any specialization toward a particular prey as it is highly carnivorous. The growth parameters $L_{\infty}$, K and t0 were estimated as 423.23 mm TL, 0.71/yr and -0.0141 respectively. The mortality parameters estimates were M= 0.935 and Z = 3.2 and F= 2.26 with an E = 0.71. The Emax (0.58) and Fmsy (1.3) estimated was in higher side than current E and F indicating the fishery is overexploited and need proper management.

# Jellyfish fisheries along the coast of Visakhapatnam, Andhra Pradesh

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A study was attempted to describe commercial jellyfish fisheries and to evaluate the economic performance of harvesting jellyfish by coastal fisherfolk along the coast of Visakhapatnam, Andhra Pradesh during 2018. The study revealed that only single species of rhizostomatid jellyfish, *Crambionella annandalei* supports the active jellyfish fishery. The fishing seasons were found to be during March to July. The total quantity of edible jellyfish caught by motorized crafts were estimated to 19,026 tonnes along the coast of Andhra Pradesh during 2018. The total landings of oral arms were estimated to 5,708 tonnes whereas estimated value of oral arms of jellyfish at landing centre level was ₹2,390 lakhs. The average operating cost per trip of the single day motorized crafts engaged in fishing jellyfishes worked out to be ₹5,795 and with a catch rate estimated at 245 kg / trip, the gross revenue earned from each fishing trip was ₹10,760. Net operating income was ₹4,965 per trip with a capital productivity of 0.54. The labour productivity estimated was 37.12kg per trip. Though, jellyfish fisheries have resulted in substantial economic benefits to fishermen, the processors and thus the local economy, it could adversely impact the jellyfish populations of the area. Processed oral arms of the jellyfish have good demand and are exported to South-East Asian countries mostly China.

# How much have we trawled? An analysis of India's trawling intensity

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Trawlers contribute a major portion of India's marine landings. Though trawling has been recognized as a significant fishing gear, the deleterious effects of trawling have also been widely recognized. Trawling in addition to being non-selective also modifies the sea bottom ecosystem which may have far reaching effects on the flora and fauna in the area. In this study we attempted to analyze the intensity of trawling in the continental shelf of India. We estimated the ratio of swept area of trawls to the continental shelf area off Andhra Pradesh and Maharashtra. Using estimates for trawling speed and length of head rope, an estimate for swept area per haul was calculated. Using this constant value, the ratio of the annual swept area (for all trawls combined for the state) to continental shelf ratio of the state was estimated. This ratio was named as the Trawling Ratio (TR). The analysis was carried annually for 34 years from 1985-2018. The mean annual TR for Andhra Pradesh was estimated to be 5.62 (SD ±2.62; range 1.71-10.49) and for Maharashtra as 3.61 (SD ±1.02; range 1.66-5.28). For both the states, TR showed an increasing trend over the study period though the rate was steeper for Andhra Pradesh. Both states have shown a declining trend in the ratio towards the end of the study period. Studies from other parts of the world indicated that the Swept Area Ratio ranged from a high of 7.926 for the Adriatic Sea to 0.004 off south Chile (Amoroso *et al*., 2018). The estimates from India do fall within this range with certain values going beyond indicating that trawling intensity in India could be quite high. Furthermore, given the fact that the entire continental shelf is not trawled due to ecological and restricted zones for fishing, such high ratios could indicate very intense fishing over the available trawling grounds. This is a first attempt to study the trawling intensity of India and is based on a number of assumptions since haul and track information is not available per trawler. The study can be refined further if fishermen provide access to log books of their fishing trips and if Vessel Monitoring Systems (VMS/AIS) are in place to track individual fishing trips for better estimates.

# Environmental factors influencing dol net catch of Mumbai coast

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Dol net is a traditional passive non selective fishing gear operated in areas of strong tidal currents along north-west coast of India. A study was carried out to understand the environmental factors influencing dol net catch of Mumbai coast through experimental fishing and assessment of major environmental variables from selected sites on regular monthly basis from 2016 to 2018. A total of 156 species belonging to 63 families were recorded in the catch with annual average catch rate of 45.75 kg/haul. Canonical Correspondence Analysis (CCA), Pearson correlation analysis and Generalized Additive Modelling (GAM) was carried out to understand the influence of environmental parameters on dol net catch and the diagnostic species for each season were identified. Four axes were identified through CCA of which, axes 1 and 2 were found to be significant and together contributed 67.7% (Axis 1: 39.91% and Axis 2: 27.78%) of the total variability. The first canonical axis was significantly loaded with the environmental variables such as current speed, chlorophyll-a and plankton density, while the second canonical axis was significantly loaded with temperature, salinity, dissolved oxygen, pH and turbidity. Axes1 and 2 separated fish assemblages based on seasonal differences. Meanwhile, there was no substantial spatial difference observed. The analysis of correlation between environmental covariates and fish assemblages revealed that the major species caught in dolnet were distributed within three groups with respect to the environmental characteristics and seasons. Based on the F value obtained from GAM analysis, the most influential environmental variables for *Harpadon nehereus, Acetes* sp., *Coilia dussumieri, Nemetopalaeamon tenuipes,* penaeids and ribbonfishes were current speed, plankton density and temperature. The total catch in dol net was most particularly influenced by current speed. Deviance explained in the final GAM model varied from 41.3% (penaeids) to 86.7% (*H. nehereus*). The plot of the best smoothing showed the range of most decisive environmental variables, where the probability of abundance of the target species is maximum. The results of CCA, Pearson's correlation analysis and GAM showed that the environmental variables, current speed, temperature, salinity, pH, DO, turbidity, chlorophyll-a and plankton densities played a significant role in structuring the catch composition during the different seasons. The seasonal migration of different species mediated by environmental variables seems to be an important factor which determines the temporal variation in catch composition. The most suitable range of environmental variables for target species were identified using GAM and predictive models were developed based on this. After further validations by using more time-series data and more data points, the GAMs developed through the study can be used to map the potential fishing grounds for dol nets along Maharashtra coast.

# Marine fisheries modelling and data mining-algorithm vs computational speed: an assessment

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Modelling marine resources, both at ecosystem level and genetic level, is replete with opportunities, challenges and of course pitfalls. Modern spurt in computational possibilities has resulted in the mushrooming of analytical dare devilry, wherein the methodologies thus far considered academic started raising their heads. The algorithms, which dictated the success and fame of any modelling procedure, especially in the quantitative genetic modelling of resources, have been faced with the challenge of brute computational power-based options. Small scale High Performance Computing (HPC) options have the power of exponentially enhancing the treatment and analytical rigours hitherto employed by data collecting agencies.

A small comparison of two variants of Restricted Maximum Likelihood (REML) Estimates of the variance components of a catfish sib data using mixed models was made in this study. The Average Information and the Asymptotic REML approaches yielded contrastingly divergent performances as regards CPU time when run in desktops. The performance got more pronounced when multi variate mixed linear models were run. Some software too astonishingly more time to perform the same operation under such conditions. A brief comparison of the CPU time is given in the above table.

However, when the same type of analysis was performed using the new HPC facility at ICAR-CMFRI, FISH, the profiles gave a different picture. The results gave a new insight leading to a new dimension towards selecting procedures and hence software while dealing with such data. The derivative free approaches to REML estimation, which are quite computationally tedious score comfortably over derivative based methods due to their comprehensive optimisation benefits.

Another attempt on putting to use the HPC for mining the field data for studying the hidden patterns associated within the main players in estimation of landings viz. gears, resources and enumerators, was made on a pilot basis and the results are also discussed.

Comparison of computational time in solving a mixed linear model

| Model/ Algorithm/ package | Estimated parameter | Computational time |
|---|---|---|
| Fullsib analysis/ single trait/ SAS/ SS3 | Heritability/ variance components | 58 secs (slight variation) |
| Fullsib analysis/ single trait/ R (lmer/ mmer) | Heritability/ variance components | 34 secs (system time) |
| Animal model/ single trait/ SAS/REML | Heritability/ variance components | 79 secs |
| Animal model/ Wombat/ single trait | Heritability/ variance components | 38 seconds |
| Animal model/ ASReml/ single trait | Heritability/ variance components | 47 secs |
| Animal model/ Wombat/ two traits | Heritability/ variance components | 67 secs (system time) |
| Animal model/ MCMCglmm/ two traits | Heritability/ variance components | 74 secs(1000 samples) |
| Animal model/ Wombat/ hexavariate | Heritability/ variance components | 82 secs (mind boggling) |

(*Intel i-5 3.4GHz 4 GB DDR3 RAM)

# Elasmobranch fishery with special emphasis on the pelagic sharks and rays from Tuticorin, south-east coast of India

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Elasmobranchs consisting of sharks and batoids form one of the largest marine fishery resources and an important demersal resource exploited by different types of gears such as trawlnet, mechanized gillnets (MGN) and hooks & line (HL) in India. In Tamil Nadu, elasmobranch is a commercially important demersal resource and exploitation of these is found to be very high and are mainly caught as bycatch. Observations on elasmobranch fishery in Tuticorin, South east coast of India for the period of nine years from 2010-2018 and data on catch, effort and species composition were collected. The monthly and annual estimates of catches were calculated following the Stratified Multistage Random Sampling Design adopted by the Fishery Resource Assessment Division, ICAR-Central Marine Fisheries Research Institute. The elasmobranch landing at Tuticorin during 2010-18 fluctuated between 623 t (2017) and 1355 t (2014) and the average for this period was 960 t. The catches varied from 317 t to 456 t for the trawl nets, 201 t to 288 t for mechanized gillnet and 54 t to 91 t in HL. The average catch in elasmobranches i.e. 40 %, 70 % & 7 % to the trawl, gillnet and hooks and line (H&L) respectively.

The pelagic sharks and rays include both oceanic and semi-pelagic species form an important resource exploited along Tuticorin and were mainly caught from multiday gillnets (MGN's) during 2010-2018. The study revealed that the pelagic sharks and rays caught as bycatch of MGNs targeting for the scombrids and other large pelagic fishes contributing to a tune of 7.6 % of total elasmobranch landing during 2010-18. The landing of pelagic elasmobranchs during the study period ranged 80 t -150 t with an average contribution of 85 t. In total, 21 species of elasmobranchs were recorded during the study period of which 13 species represented the pelagic sharks and rays (7 sharks and 6 rays) and the IUCN status was detailed in this paper. The dominant pelagic sharks and rays are bigeye thresher, *Alopias superciliosus* and spinetail devilray, *Mobula japonica*. The seasonal resource mapping of pelagic sharks and rays revealed that fishing grounds of MGNs was between 77° E to 80°E longitudes & 7° N to 9° N latitudes. The study revealed that pelagic sharks and rays are known to be biologically vulnerable to overfishing and they are heavily targeted and being overexploited and there is a need of immediate management. The study complements and augments existing scientific advice for the conservation, management and gives priority for the vulnerable pelagic sharks and rays.

# Impact of operational modifications of trawling on exploited marine resource composition along Mangalore coast

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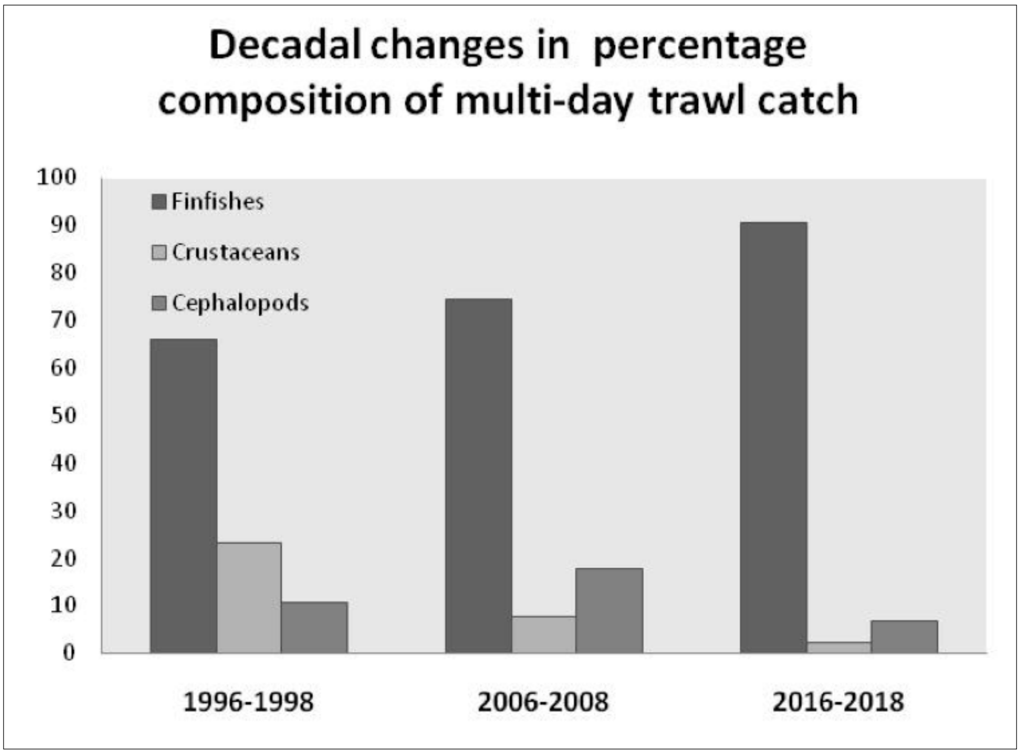
Trawling, the highest contributor in the landings of marine fisheries resources in India have undergone several changes in its operation and fishing pattern. Reduction of catch per unit effort led to many innovations in fishing operations. The modifications in trawl nets and trawling operations have taken place at a more rapid pace during last three decades. This paper analyzes the catch trends of three decades, using the annual averages of cluster of three years representing each decade, ie, 1996-1998 for the first decade, 2006-2008 for the second decade and 2016-2018 for the last decade. Reduced profitability led to the unhealthy competition in trawl fishery which was reflected in installation of enhanced engine power, diversified trawl designs, high storage capacity and increased trip duration. These modifications were mostly demand driven and had a noticeable impact on fishery which is reflected on the species-wise landings. Present study was focused to bring out the decadal changes observed in the species-wise or group-wise landings in the trawl fishery related to the operational changes brought in during the three decades. Composition of trawl fishery during three decades were investigated by classifying them into different categories like, demersal fishes and pelagic/column fishes; group-wise classification like finfish, crustaceans and molluscs. Trawl catch from single day operating trawlers and multi-day operating trawlers were analyzed separately.

In single day operating trawlers group-wise analysis of fishery did not show noticeable variations in terms of the landings of finfishes, crustaceans and molluscans. Crustacean contribution fluctuated between 27-45%; finfishes 29 to 52% and molluscs 1-3% during these three decades. However, wide variation in the contribution of these three components of fishery was observed in multiday trawlers. The finfish contribution increased from 65 to 75% in 2006-2008 and further to 91% in 2016-2018. A sharp reduction from 23% in 1996-1998 to 7% in 2006-2008 and further to 2% in 2016-2018 was recorded for crustaceans landing. Cephalopods landings showed an increased trend with 10 to 17% during 1996-1998 and 2006-2008 respectively, but with domination of finishes during 2016-2018, the percentage of cephalopods reduced to 7%.

There was not much difference in the contribution of demersal fishes from the single day trawlers during three decades and it varied between 12 and 13%. However, the demersal fish contribution from the multiday trawl fishery showed sharp reduction from 71% in 1996-1998 to 52% in 2006-2008 and to 48% in 2016-18. This clearly indicated that there was a gradual shift from bottom trawling to midwater/pelagic trawling over the period of time. Twenty major species landed from trawl were studied during the three decades for understanding the catch trend. Out of 20 species that contributed to the fishery (by quantity), the contribution of demersal fishes were reduced from 11 species in 1996-1998 to 9 species in 2006-2008 and to 4 species in 2016-2018. The species wise analysis of multiday trawlers landings revealed that even though *Nemipterus randalli* remained as the major contributor to the trawl fishery throughout last three decades, during 2006-2008, ribbonfishes and cuttlefishes replaced the demersal group domination as second and third dominant species replacing




stomatopods and soles. In 2016-2018, Indian mackerel was the most dominant species after *Nemipterus randalli and Priacanthus spp* and of 20 major species landed, 16 were pelagic species showing significant confirmation of the shift in fishing pattern by trawlers from bottom trawling to pelagic trawling. Even though it is a known fact that the innovations are prevalent in trawl fishery in terms of speed and pattern of trawl operations, there is no documented proof available to establish the changes since the country has not developed effective MCS in marine fisheries. However the analysis of composition of the fishery resources landed will provide reliable information for further studies and would form baseline information for evaluating ongoing fishing practices in terms of sustainability.

# Marine finfish and shellfish larval dynamics off Visakhapatnam, Andhra Pradesh

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Abundance and distribution of marine finfish and shellfish larvae were studied off Visakhapatnam waters during 2017-2019. Larvae were collected during experimental trawling trips off Visakhapatnam. The larvae collected were filtered using standard filtration protocol using 300 µ mesh sieve and fixed in 10% formalin in the laboratory. The volume of water filtered was calculated from flowmeter readings. Total larvae collected per sample were enumerated and identified to genus level wherever possible. The average monthly plankton concentration off Visakhapatnam was 0.14 ml/m$^3$ with the range being 0.02-0.54 ml/m$^3$. The highest plankton concentration was seen in May and the lowest in July-August. Concentration of plankton showed a negative correlation with sea surface temperature. The correlation coefficient was estimated to be -0.51. Fish eggs were the most dominant category in the sample collections (average 26 nos./sample), followed by shrimp post larvae (11.9), other crustacean larvae (7.5), molluscan spat (5.6) and fish larvae (2.3). Correlation analysis indicated that fish eggs and molluscan spat were negatively correlated with sea surface temperature and conversely, fish larvae, shrimp post-larvae and other crustacean (crab and squilla) larvae were positively correlated with sea surface temperature. Seasonal variations were seen in the concentration of fish eggs and shrimp post-larvae. Fish egg concentrations were highest in April and fish larvae concentrations were highest in June indicating that these are products of spawning in the months leading to April. Shrimp post-larvae concentrations were highest in September indicating their spawning period to be during July-August. Distinct areas of higher incidence of fish eggs, fish larvae, shrimp post-larvae and molluscan larvae were seen off Visakhapatnam. Fish eggs were more widely distributed, with highest concentrations in areas closest to the shore. Fish larvae on the other hand were almost exclusively found in areas closest to the shore. Molluscan larvae were distributed further off-shore in areas of depth 20-30 m. Shrimp post-larvae similar to fish larvae were found in areas closest to the shore.

# Stock status of *Sepia pharaonis* off Maharashtra coast

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The pharaoh cuttlefish *Sepia pharaonis* Ehrenberg, 1831 is a commercially important species exploited by trawl net along Maharashtra coast. In recent past, fluctuation in pharaoh cuttlefish landing and targeted fishery stressed to find out stock status of the resource along Maharashtra coast. In the present study, fisheries reference points were estimated using Catch-MSY (CMSY) and Bayesian Schaefer production model (BSM). The trawl landing data (tonnes) and fishing efforts data (actual fishing hours) collected using Stratified Multi-stage Random Sampling method from 2007 to 2018 along Maharashtra coast were used as input data for both the models.

The average landing of pharaoh cuttlefish ranged from 3098 t (2007) to 3056 t (2018) with peak landing (7204 t) in 2017. Average landing during the period was 3015 t and catch per hour (CPUE) 1.23 kg/hr. The MSY estimated for pharaoh cuttlefish by Bayesian Schaefer Model (BSM) using catch and CPUE along Maharashtra coast is 2900 t (CL=2.45-3.42). This may be result of increased fishing pressure since 2015. Immediate drop in landing observed when (2015 & 2017) landing crossed the MSY level. Historical trajectory and present stock status show high fishing pressure on resources. Recent increase in targeted fishing efforts is attributed to high price realised by pharaoh cuttlefish in the fish market and increased operation high speed mid-water trawling along Maharashtra coast. The demarcation of spawning aggregation area for the pharaoh cuttlefish will help sustain fisheries along Maharashtra state. Following table gives details of reference points estimates by Bayesian Schaefer model for *S. pharaonis* along Maharashtra state.

Table: Bayesian Schaefer Model (BSM) using catch and CPUE

| Metric | Estimates | Confidence limits (95%) |
|---|---|---|
| MSY ('000 t) | 2.9 | 2.45-3.42 |
| Bmsy ('000 t) | 6.88 | 5.21-9.09 |
| Fmsy | 0.42 | 0.3-0.59 |
| B/Bmsy (for 2018) | 0.90 | |
| F/Fmsy(for 2015) | 1.17 | |

# Perspective on management of marine fisheries of Tamil Nadu beyond territorial waters

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At present the marine fisheries of Tamil Nadu is regulated and managed based on Tamil Nadu Marine Fisheries Regulation Act, 1983 with suitable amendments from time to time. This regulation is applicable to all the boats operated from Tamil Nadu landing centres/harbours irrespective of their area of operation. Once the newly crafted 'The Marine Fisheries (Regulation and Management) Act 2017' comes into effect, the area beyond 12 nautical miles (Nm) comes under the control of Union government.

The salient points proposed in the new Act are:

- The boats must get a permit issued by the union government to fish between 12 Nm and 200 Nm of our EEZ or beyond and is issued with a fee.
- There will be specified ports for the landing by such boats.
- The boats which are fishing without permit in this area will be considered as illegal and such boats will be impounded and the owner or master of the boats shall be punishable with a fee as prescribed
- In due course, it will consider increasing the presently available area to the traditional fishermen in the territorial waters(TW)

Current scenario in Tamil Nadu:

## Fishing

- There are three categories of boats in terms of their area of operation- those which are always fishing beyond the TW, those which are fishing within the TW and those which fish in both the waters depending on abundance of the targeted resources.
- The fishing in TW and beyond includes both mechanized and motorized boats.
- No restriction on area of fishing except on mechanized boats which are prohibited from fishing within 3 Nm from the coast in the territorial sea. But as per 'The Tamil Nadu Marine Fisheries Regulation (Amendment) Act, 2016, mechanized fishing vessels should fish beyond 5 Nm from the coast in the territorial waters. Motorized country craft having motorized means of propulsion either from single engine or multiple engines having capacity of 8 hp and above shall not fish within 3 Nm from the coast in the territorial waters. But this is not yet implemented.
- The trawling in Coromandel Coast of Tamil Nadu extends to Andhra waters which often invites the wrath of the local fishermen and even confiscation of the trawlers from Tamil Nadu.

## Landing Centres

- Fishing harbours are mainly used for landing and berthing by mechanized boats. Majority of the landing centres for motorized and non-motorized boats are situated in the respective villages from where their fishermen go for fishing.

## Challenges

- Whether the boats which use to fish in both TW and beyond can continue to do so or they will have to opt only one area for fishing.

- Making the entire territorial sea free of mechanized fishing especially trawling will also be a huge challenge as the depth ofoperation of majority of trawlers is below 80 m.

### Plausible options

- As mechanized vessels targeting deep sea resources naturally come under the permit system, dual permit system can be introduced for traditional motorized boats which seasonally fish beyond TW.

- Registration of vessel and issue of permit should be done separately by a dedicated wing of the union government.

- Specifically earmark the limit on area of fishing and ensure that the landings by theboats areat the respective ports of registration.

- Even if we impose a restriction on the number of units to fish in an area, there is a possibility of effort creep. So introduce a limit to the size for boat, engine capacity and sizeof net.

- Part of the existing harbors can be earmarked for landing of boats which fish beyond territorial waters till separate ports are ready.

- Log system along with VMS can be introduced in all the boats. Already AIS is installed in majority of multiday deep sea gillnetters from Chennai and Tuticorin.

- In addition to the permit, token system may be introduced for the boats as being practiced for mechanized trawlers in Gulf of Mannar and Palk Bay.

- Participatory mode of fisheries management will be more effective for both TW and the area beyond TW.

# A comparison of length-frequency versus statolith age analysis of *Uroteuthis (Photololigo) singhalensis* in eastern Arabian Sea

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Loliginid squids are a commercially important group of neritic squids in the coastal marine waters in tropical and temperate regions around the world and are valuable resources in many areas. *Uroteuthis (Photololigo) singhalensis* is listed among the commercial species of loliginid squid exploited from the China Sea to the eastern Arabian Sea. Though this species is distributed from western Pacific to the Indian Ocean from the Andaman Sea, the Bay of Bengal to the Arabian Sea and the eastern African coasts, there is little information on the life cycle of this species throughout its distributional range. The objective of this study is to determine the length-weight relationship, age and growth of *U. (P.) singhalensis* off eastern Arabian Sea. Most earlier estimates of growth in tropical squids are derived from length frequency analysis. The accuracy and precision of squid growth estimates have been enhanced by using statolith increment analysis, hence statolith increment is used to determine age and individual growth rate of squid off the eastern Arabian Sea. Further, the comparison of the length frequency analysis with statolith ageing techniques is attempted.

Over 1,800 squids (males-825; females-701; unsexed-284) were sampled from trawlers during 2013 to 2016 in the eastern Arabian Sea off southeast coast of India; their growth was analyzed by traditional fisheries methods (ELEFAN). From 2017 to 2018, 148 squid from trawlers were aged using statolith increment analysis. To estimate the relationship between dorsal mantle length (ML) and weight (TW) for males and females the power equation $TW = a\,ML^b$ was used. There was no significant difference in the ML-TW relationship between males and females.

# Reproductive status of blood spotted swimming crab *Portunus sanguinolentus* (Herbst, 1783) landed off Cochin, Kerala

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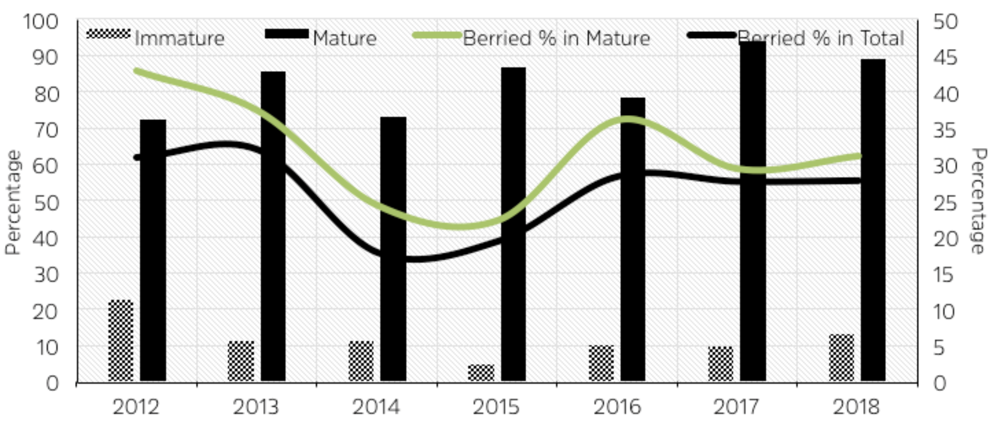
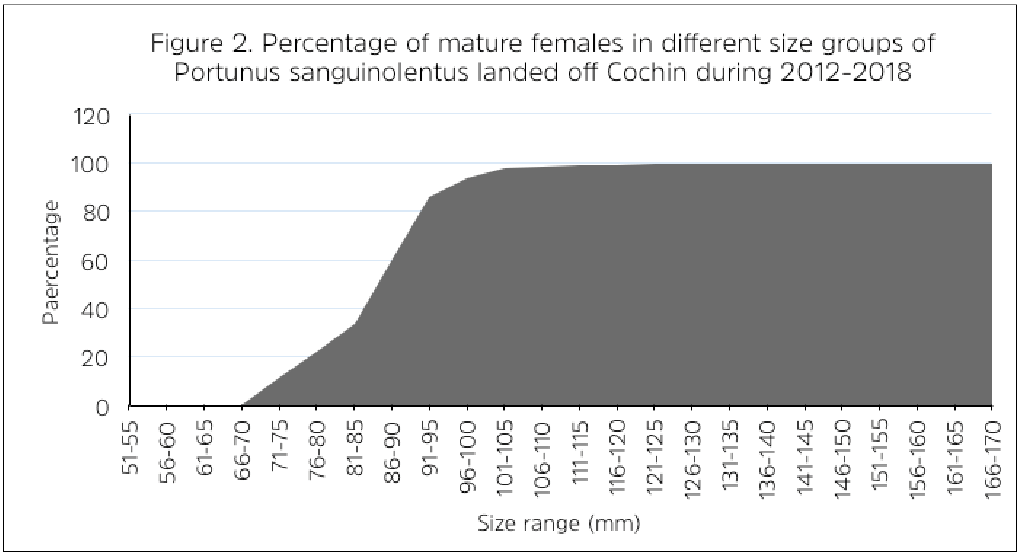
*Portunus sanguinolentus* (Herbst, 1783) is commonly known as Blood Spotted crab or Three-spot swimming crab is an important commercial crab enjoying a wide distribution along the Indian coast. Popularly known as 'pottu njandu' in Kerala, landed mainly in trawls and ranks first in the landings in most the years, recording about fifty percent of the crab landings of the state during 2012-2018, except in the year 2014 (28%). Females are dominating the fishery and their sizes ranged between 55-170 mm carapace width (CW) with 90-110 mm sizes dominant contributor to the landings. Berried females are recorded throughout the year without any regular dominance in particular month, however, during March-May good percentage of them are observed in overall landings. The percentage composition of maturity stages recorded in landed crabs during 2012-2018 is presented in Figures-1& 2. The newly spawned eggs are in bright yellow/orange in colour and by the time of hatching the colour changes to dark grey. It takes 8-10 days to complete the embryonic development before hatching to the zoea. The most potential sizes are between 90-120 mm CW and the fecundity varied between 80960 -2748675 numbers with an average of 1057175 nos. The average size of the egg is about 270 μm. Captive studies showed that the species is capable of multiple spawnings, with a maximum of three in an intermoult cycle. Size at maturity (Lm 50) was estimated at 87.35 mm CW and all the females were mature above 120 mm carapace width and below 70 mm CW mature

Figure 1. composition of maturity stages in landed P.sanguinolentus females during 2012-2018

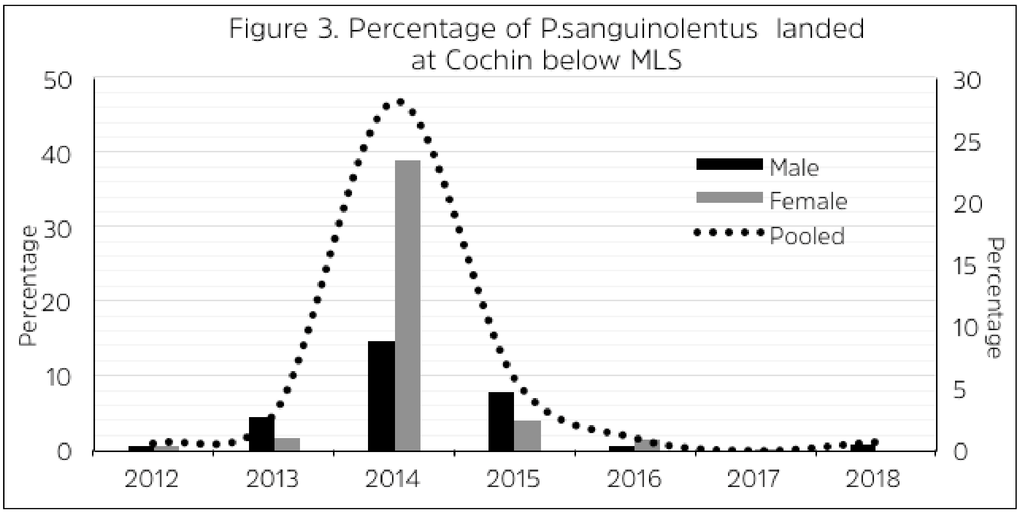





females were not recorded in the landed crabs. The smallest size of the mature and berried female recorded in the landings was 71 mm CW/22 g and 80 mm CW/32 g respectively.

In landings, males comprised the sizes between 51-170 mm carapace width (CW) with 91-105 mm formed the major size group contributed to the fishery. In males, 100 % maturity was observed in crabs above the size of 95 mm CW and all the crabs were mature and sizes below 60 mm CW were immature. The smallest size of the mature male crab recorded in the landings was 60 mm CW/16 g.

Minimum Legal Size (MLS) was implemented in Kerala in 2015 and for *P. sanguinolentus* MLS is fixed at 70 mm CW and the details of catch composition below MLS is given in Figure 3. In Kerala the strict enforcement of the MLS in in practice in the recent years and it is very much reflected in the landings. The findings on the reproductive biology and related information on the species will have paramount importance in the management of the fishery and will form key components while considering the measures for the sustainable utilization of the resource, atleast in this part of the coast.



# A modified productivity and susceptibility analysis (m-PSA) to evaluate the status of marine fish stocks in Gujarat, India

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Marine capture fisheries of Gujarat state is trawl dominated and harvest quite a large number of target and non-target resources. Conventional stock assessment tool requires a wide range of data pertaining to length frequency distribution, the abundance that too over a wider temporal scale which in most cases are not available or if available is in incompatible form which cannot be used with these tools. The need to manage all the harvested stock (target or non-target, high value or low value) in a sustainable manner warrant scientific evaluation of their status to start with. Productivity and Susceptibility Analysis (PSA) originally developed by NOAA offers a tool which incorporates all the available information on the stock/ species either on continuous or scattered way to arrive at a status of the stock in terms of an index refereed as Vulnerability Index. The method is simple and can be applied to most of the harvested stocks. A modified version of PSA (m-PSA) with addition and subtraction of Productivity and Susceptibility attributes found available or suitable for the harvested stocks of the northwest coast of India was attempted. "Productivity" is defined as the capacity of the stock to recover once the population is depleted (Stobutzki *et al.* 2001b). This largely reflects the life-history characteristics of the stock, whereas "Susceptibility" is defined as the potential for a stock to be impacted by a fishery. In a present study, ten productivity and thirteen susceptibility attributes were selected for analysis. The Productivity attributes are- Population growth rate (r), max age (tmax), max Lt (Lmax), age at maturity (tm50%), growth coefficient (K), natural mortality (M), fecundity, breeding strategy, recruitment pattern, mean trophic level (MTL). Susceptibility attributes are Area overlap, Vertical overlap, seasonal migration, schooling/aggregation and behavioral responses, morphology affecting capture, the value of fishery, management strategy, fishing rate relative to M, the sum of spawners no./ Sum of total no., Fishery impact to habitat, Bcurr/Bmsy, Fcurr/Fmsy, breeding season/fishing effort. The PSA also allows us to estimate the Vulnerability Index for the stock as $v = [(p-3)^2+(s-1)^2]^{0.5}$, where P and S are productivity and susceptibility scores. The study was extended to 37 major stocks harvested in the region with an aim to visualize the present level of fishing stress on the stocks. The resources like *Rhinobatos annandalai, Panulirus polyphagus, Scoliodon laticaudus, Plicofollis tenuspinis* are grouped under the highly vulnerable category and most of the other resources belong to the moderately vulnerable group. Fishery resources like cephalopods, penaeid prawns, tunas, mackerels, anchovies and perches were less vulnerable than the other resources. The study will help in prioritizing species for more focused investigation, which warrants precautionary approach towards their sustainable exploitation and management.

# Fishery and exploitation status of black clam, *Villorita cyprinoides* from Vembanad Lake, Kerala

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The black clam, *Villorita cyprinoides* (Family Corbiculidae) is the most important clam species contributing about 90.9% of the total clam landings from three estuaries in Kerala i.e. Ashtamudi, Vembanad and Chettuva with Vembanad Lake contributing 90.2% to the total clam fishery. In 2018, about 99.27% of black clam production was contributed by Vembanad Lake, the largest estuary, 96 Km long on the west coast of India. More than 5,000 fishermen are involved in the fishery which includes 2,000-2,500 of active fishers. Fishery, population characteristics and stock estimates of *Villorita cyprinoides* were carried out from 2014-2018. Minimum legal size (MLS) of black clam, *V. cyprinoides* was fixed at 20mm using size at first maturity as a biological reference point. Based on the recent catches of *V. cyprinoides* from Vembanad Lake, about 5% of the catches consist of juveniles. The production of black clams declined from a peak of 75,592 t in 2006 to 52238.91 t in 2018. The asymptotic length ($L_\infty$) and growth coefficient (K) were estimated at 51.45 mm and 0.74 $y^{-1}$ respectively from fishery samples. However, these estimates may vary if clam beds are also sampled. The mortality parameters, the instantaneous total mortality rate (Z), fishing mortality (F) and natural mortality rates (M) were estimated at 3.13, 1.89 and 1.24 respectively. The length structured Virtual population analysis (VPA) revealed a heavy fishing pressure on length group between 31 and 33 mm. Exploitation ratio (E), Exploitation rate (U) and $E_{max}$ was estimated at 0.6, 0.4 and 0.69 respectively. The results of this study will serve as baseline information for formulating future management measures.

# Fishery, biology and population parameters of the sand lobster *Thenus unimaculatus* (Burton & Davie, 2007) landed by the trawlers off Sakthikulangara fishing harbour along the south-west coast of India

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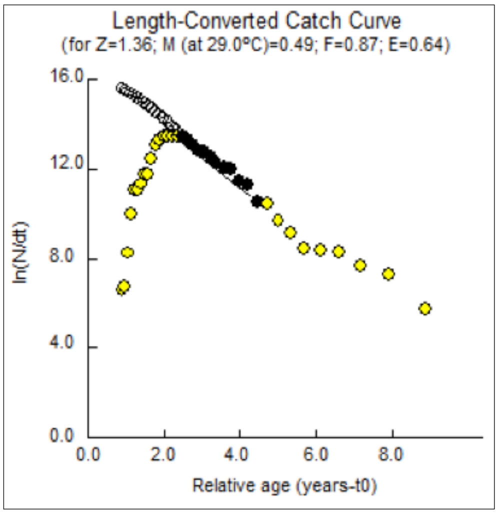
The average annual landing of *Thenus unimaculatus* from trawlers off Kerala during 2011-2018 was 22.6 t of which 80% was landed at Sakthikulangara fishing harbour off Kollam which constitutes about 0.01% of the total crustacean landings. Females slightly outnumbered males in the catch (1:0.9) and peak fishery was observed from November to February. Total length varied between 76-250 mm in males and 66-250 mm in females. Length at recruitment (Lr ) was 68 mm. The parameters of the length-weight relationship were estimated as: a = 0.108, b = 2.63, r2 = 0.82 for males and a = 0.092, b = 2.676, r2 = 0.89 for females which was not significantly different (p>0.05) between the sexes. Growth parameters estimated by von Bertalanffy's growth equation were: $L_\infty$ = 261 mm, K (monthly) = 0.028, t0 =-0.0028, tmax=8.8 years, Lm50 = 145 mm and Z=1.36, M= 0.52, F= 0.87, E=0.64, Emax= 0.782 for *T. unimaculatus*. The length at 50% capture (Lc50) was 145 mm which coincides with Lm50 and which corresponded to an age (tc) of 2 years. Absolute fecundity varied from 10140 to 47323 mature eggs and the relative fecundity varied from 65.3 to 178.5/g of body weight respectively.



# Feeding strategies and diet composition of flat needlefish *Ablennes hians* (Valenciennes, 1846) (Beloniformes: Belonidae) in the southeastern Arabian Sea

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The study describes the feeding habits, diet composition and prey diversity of one of the commercially important marine needlefish species: flat needlefish *Ablennes hians* based on 396 specimens collected between October 2015 and September 2017 from the Kerala coast. The female individuals ($n$ = 190) ranged from 45-122 cm TL and 90-2585 g TW, whereas males ($n$ = 206) ranged from 53.5-114.5 cm TL and 155-2255 g TW. The mean total length of female needlefish, 87.0 ± 0.9 cm was found to be significantly different from the males, 81.9 ± 0.8 cm (independent $t$ test, $p$< 0.001). Similarly, the mean total weight of female needlefish, 910.1 ± 32.8 g was found to be significantly different from the males, 794.6 ± 26.4 g (independent $t$ test, $p$< 0.05). The length frequency distribution of male and females was not significantly different (Kolmogorov-Smirnov test, $P$> 0.05). Females constituted 48% and males 52 % in the population with an overall sex ratio of males to females was 1: 0.92 and did not significantly differ from the expected 1:1 ratio (chi-square $df$= 1; $p$ > 0.05). The stomach contents of flat needlefish were identified in to 18 different food items belonging to three major groups such as teleost, crustacean and mollusc. The index of relative importance showed that teleost were the most preferred food items(%IRI = 65.43%) followed by mollusc (%IRI = 32.91) which constituted as the secondary food items and crustacean (%IRI = 1.66) and other (%IRI = <0.1) as accessory or accidental food items. The teleost in the diet of needle fish were mainly constituted by scads, sardines, anchovies, codlets, threadfin breams, halfbeaks, puffers whereas crustacean represented by crabs, non-penaeid and sergestid shrimps and mollusc were constituted by cephalopods and pteropods. From the diet composition of flat needlefish it is evident that most of the prey items were from the pelagic zone such as carangids, sardines, anchovies, codlets, halfbeaks, paste shrimp and pteropods and few others from the benthic zone such as threadfin breams, puffers, penaeid shrimps, brachyuran crab and squid. This clearly indicated that the species is a carnivorous and active pelagic predator, predominately consuming teleost fishes and also an opportunistic feeder which might perform vertical migrations in search of food. Prey biodiversity analyses indicated that there was no significant variation in the prey items between the sexes and immature (juvenile) and mature (adult) specimens. Similarly, a non-significant difference in vacuity index (VI) and fullness index (FI) were observed between sexes ($p$> 0.05) and juveniles and adults ($p$> 0.05). Mean number of prey per stomach (Nm/ST) was found to be higher in females and juveniles than males and adults, respectively whereas mean weight of prey per stomach (Wm/ST) higher in females and adults. Analysis of similarities (ANOSIM) test also indicated that there was no difference in prey types and preferences between sexes (global R = -0.25, $P$> 0.05) and juveniles and adults (global R = 0.5, $P$> 0.05). The data generated in the present study provides a first reference on the detailed information on feeding biology of the flat needlefish which can be used as baseline information for proper management and conservation of this species in the region.

# Reproductive biology of the Bowmouth guitarfish *Rhina ancylostoma* (Batoidea: Rhinidae) in eastern Arabian Sea, India

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The Bowmouth Guitarfish *Rhina ancylostoma* is caught by trawler and gillnetters in eastern Arabian Sea (Karnataka, south-west coast of India). However, little is known of the life history of this species. The aim of this study was to analyse critical biological information on size, sex composition, length-at-maturity (*LT*50), length -mass relationship and diet. Sampling was carried out at two fisheries landing sites located on the west coast of India, from 2016 to 2019. The largest total length recorded for this species was 295 cm, weighing 127 kg and females were larger than the males. A total of 369 individuals, from 44.0 to 295 cm total length (*LT*), 0.2 to 127 kg total mass (*MT*) were used for the study. The length-mass relationships were not significantly different between the sexes. The length-mass relationship (combined sexes) was derived as $MT= 0.006604LT^{3.027504}$($r^2$=0.979). Co-efficients '*a*' and '*b*' of the length-mass relationship were estimated as 0.009003 and 2.960941($r^2$=0.982) for females and 0.005467 and 3.112696 ($r^2$=0.978) for males, respectively. The length-at-maturity (*LT*50) for females and males was estimated to be 183.0 and 164.0 cm *LT*, respectively. This species possesses two functional ovaries: the ovarian cycle and gestation run concurrently. Number of embryos ranged from 2 to 8 and the size at birth was estimated to range between 44.0 to 50.0 cm *LT*. Overall sex ratio favoured females at the rate of 1.17:1. Dietary analysis of stomach contents (%*I*RI) revealed that *R. ancylostoma* feeds primarily on teleosts (73.3%), crustaceans (20.5%) and mollusca (6.2%). Seasonally, gravid females entering coastal waters for parturition and feeding, becoming extremely vulnerable to trawl and gillnets used along Karnataka coast. The species is categorized in IUCN Red List as "Critically Endangered", hence evidently warrant the urgent need for an effective management plan to avoid further depletion of population.

# Conservation status of marine fish species of Andhra Pradesh

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Nearly 384 species of finfishes, representing 92 families and 21 orders are reported from the coast of Andhra Pradesh. Twenty of these species (5.2% of total) fall in the threatened groups (Critically Endangered, Endangered and Vulnerable) as per IUCN classification. Two species namely *Pristis microdon* and *Rhynchobatus djiddensis* are 'Critically Endangered'. Nine species consisting of 6 sharks, 1 sawfish and 2 rays fall in the 'Endangered' category. Nine species consisting of 3 sharks, 4 rays, 1 shad and 1 grouper fall in the 'Vulnerable' category. Eighty percent of the threatened species are elasmobranchs indicating the high levels of risk faced by these species. Eleven species consisting of 6 sharks, 2 rays, 1 tuna, 1 seerfish and 1 lizardfish fall in the 'Near Threatened' category. Of the remaining, 214 species fall in the 'Least Concern' category and 139 in the 'Data Deficient' category. Maximum number of species in the 'Least Concern' category is from Perciformes, Clupeiformes and Scorpaeniformes. All the reported species in Beryciformes, Gasterosteiformes and Syngnathiformes fall in the 'Least Concern' category. Most of the 'Data Deficient' species are from Perciformes and Pleuronectiformes. Furthermore, all species in Aguilliformes, Lophiiformes and Ophidiiformes fall in the 'Data Deficient' category. Out of around 94 species of pelagic fishes, *Tenualosa toli* falls in 'Vulnerable' while, *Thunnus albacores* and *Scomberomorus commerson* falls in 'Near Threatened' category. From the results, it is evident, that strong conservation measures have to be put in place for elasmobranchs in Andhra Pradesh.

# Food and feeding biology of moonfish, *Mene maculata* (Bloch & Schneider, 1801) along eastern Arabian Sea

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Study on the food and feeding habits are major aspects of fishery biology on which the behaviour, habitat and morphology of many of the fishes depend. Hence the tropho-dynamics needs to be understood fully, not only for commercial harvests, but also for formulation of policy for management of its fishery. *Mene maculata* (Bloch and Schneider, 1801), commonly known as moonfish, is an emerging fishery resource along the Konkan -Malabar Coast, especially after the introduction of light based fishing bypurse seiners. Though the species formed a considerable fishery along the eastern Arabian Sea, there is no report on the food and feeding biology from this region. The samples of moonfish for the present study were collected on a fortnightly basis for two years from December 2015 to November 2017 from the mechanised fishing vessels (multi-night trawlers and purse seiners) landed at Mangalore and Malpe Fishing Harbours in Karnataka. The fish samples were dissected and food items obtained from the gut were sorted, identified, weighed and counted. The variation in the food composition, feeding habit, strategy of feeding, the trophic diet breadth, relative level of dietary specialisation and degree of trophic overlap of adult and juvenile moonfish were determined. The TROPH value and Omnivory Index (OI)was also estimated. The moonfish was found to be carnivorous, where juvenile fed mainly on the small zooplankton crustaceans but adults shifted to cephalopods, larger zooplankton of crustacean and fish origin. The feeding strategy of juvenile moonfish was specialised, where as the adult fish was found to be a generalised feeder. Diet breadth and dietary specialization of juveniles indicates low spectrum width of prey items and relatively less number of major preys while a wider spectrum width and relatively large number of preys were found in adults. The degree of trophic overlap between juveniles and adult was found to be insignificant. The estimated TROPH value for moonfish was 3.56 (SE = 0.81) and the Omnivory Index (OI) was 0.665.

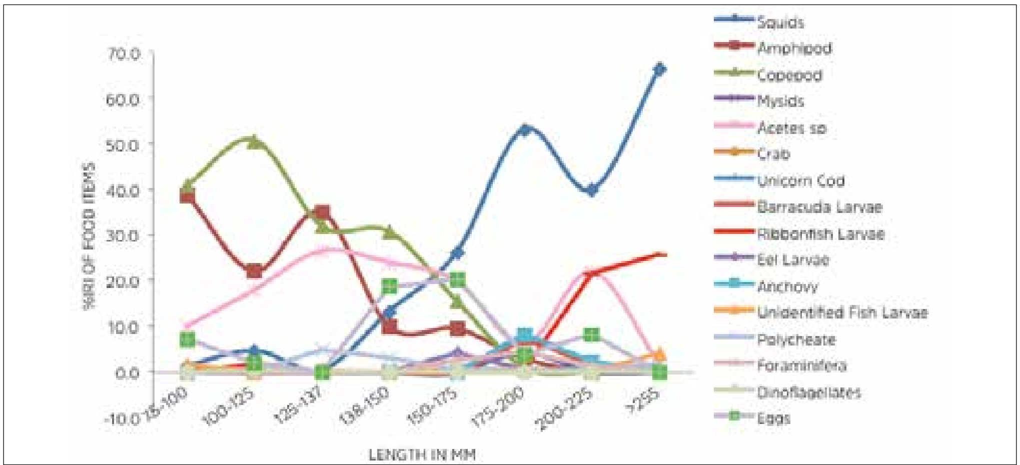


Fig 1. Graph showing the food items in the gut of moonfish of different length class

# An assessment of the fishery and reproductive biology of snappers of Kerala

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The family Lutjanidae collectively known as snappers, contains 17 genera and 105 species, which are mainly confined to tropical and subtropical marine waters, with few occurring in estuaries. In India, a total of 35 species under 8 genera of snappers were recorded, of which nearly 26 species are commercially important. In Kerala, 20 species contribute to the snapper landings in the state. Snappers are important fisheries resources, with high commercial value and play an important role in the livelihoods and food security of many local communities worldwide.

A detailed taxonomic and biological study on selected commercially important snapper resources was conducted during the period 2003-2016. The present work also aims to provide an overview of the current status and trends of these resources and to find alternative sources of information that could be used to determine the status of snapper fisheries. A decadal analysis of the snapper fishery of the state reveals an interesting pattern in fishing. An estimated 1928 t of snappers was landed in 2002; landings showed varied fluctuations with a highest landing of 2023 t in 2010, followed by a decline till 2016. Major contributors to the commercial landings were *Pristipomoides typus*, *P. filamentosus*, *Lutjanus vitta*, *L. kasmira*, *L. bohar*, *L. lutjanus*, *L. argentimaculatus*, *L. rivulatus*, *Aprion*

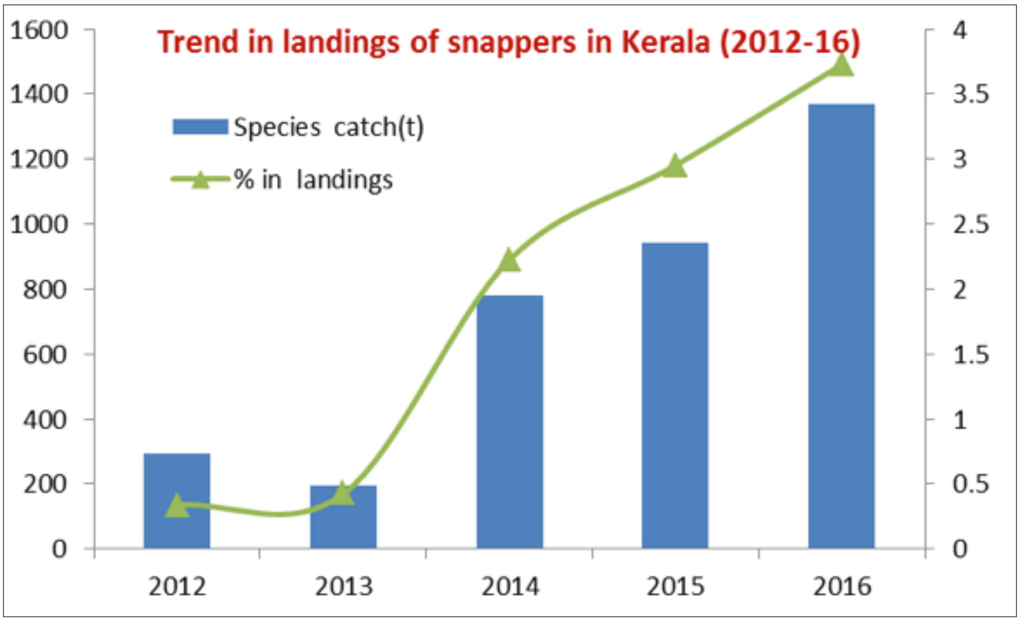


Fig. 1. Trend in the landings of snappers in Kerala during 2012 -2016

*virescens, Paracaesio sordida, Pinjalo pinjalo and Pinjalo lewisi.* During the years, fishery was good during the months December -June but peaked during April -June. A change in the fishing areas of operation and landing was noticed subsequently with landings being more in the southern Kerala districts due to non-fishery reasons.

A study on the biology of few species shows that *Pristipomoides typus* and *P. filamentous* were landed throughout the year with length range of 105-805 mm and 190 -840 mm respectively. Recruitment into the fishery for the two species was seen during January and August respectively. *Lutjanus gibbus* another commercially important fish had a length range of 220-470 mm in the fishery with recruitment in August. *Pinjalo pinjalo* and *Pinjalo lewisi* are new entrants in 2004-06, but contributed to the commercial fishery by 2014 due to the preference in the domestic and export market. *Pinjalo lewisi* occurred in the fishery during the cooler seasons of October -December which was also the spawning season. Fishes with mature testis had total length of 385 -415 mm and body weight 804 -1040 g.

During the last year, India was at 10th place out of the countries that exported the highest dollar value worth of frozen fish. India's exports amounted to $581.1 million which was 2.5% of total exported frozen fish. Of the frozen fish exported from India, snappers are an important commodity. Hence an understanding of their biology and fishery potential is very important in the present day context.

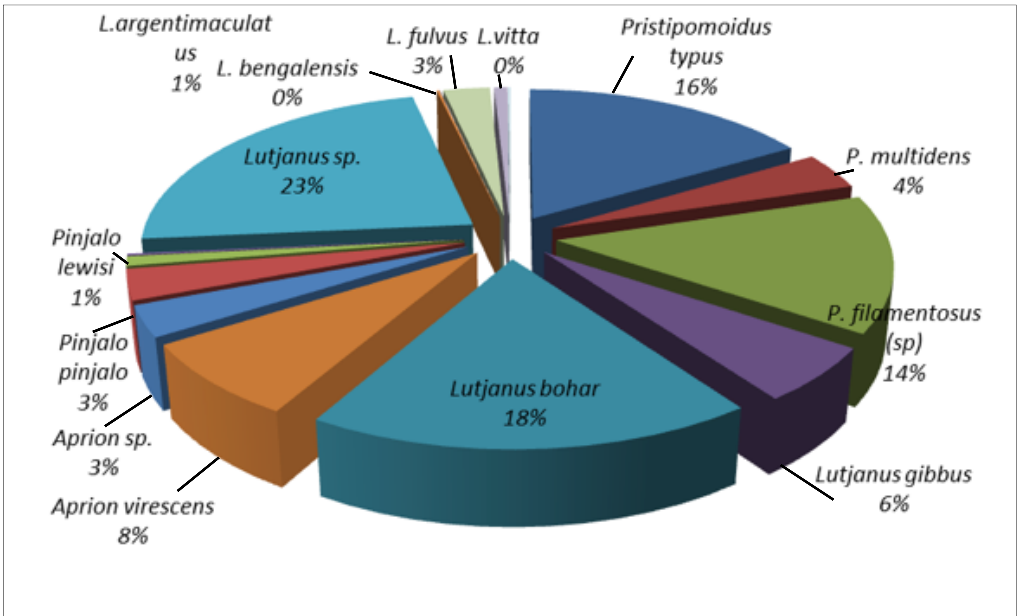


Fig. 2 Species composition of the major groupers in Kerala 2012-2016

# Trophic interaction, ecosystem structure and function in Mandovi estuary of Goa, India

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The state of Goa, which is the smallest state in India has a coastline of 101 km and seven major rivers join the sea along the coast making the area a very productive one. Among these Mandovi and Zuari are the most important rivers interspaced by Kumbarjua Canal forming a major estuarine complex. Mandovi Estuary is a prominent water body along west coast of India, located between 15° 25'N to 15° 31 N and 73°45' to 73° 59'E, about 60 km long and 1.6 km wide and well mixed throughout the year except during monsoon months when vertical stratification occurs. Hydrographic parameter fluctuates widely in the Estuary over the year and it is never in a steady state. The river receives heavy freshwater discharge during south west monsoon and flow in the estuary is mainly tidal. The nutrient influx in the estuary supports good fishery. The mangroves on the estuarine banks provide productive breeding ground to many marine species. However anthropogenic activities and climate change could impact the flora and fauna and damage the ecosystem.

A trophic mass-balance model of Mandovi Estuary was constructed using Ecopath with Ecosim software for the period 2013-2017. Fifteen functional groups were defined and their diet composition was studied. The ecological groups identified were mammals, marine birds, large pelagics, large benthic carnivores, small benthic carnivores, small pelagic, small benthopelgics, benthic omnivores, oysters, shrimps, crabs, benthos, zooplankton, phytoplankton and detritus. The fishery had a mean trophic value of 2.95. Resource biomass structure of the Mandovi estuarine ecosystem indicates that it is primarily a low trophic level driven ecosystem. Ecotrophic Efficiency (EE) of most of the ecological groups except that of marine mammals, birds, large pelagics and large benthic carnivore is near to 1 indicating that the groups are highly preyed upon or fished. The total system throughput estimated is 4712.19 t/km$^2$/year which is comparable with other tropical estuarine ecosystems. The total primary production/total respiration ration of 1.174 implies that Mandovi estuarine ecosystem is in a developing stage with its ratio greater than 1 and are prone to ecological changes, including anthropogenic impacts.

Net system production value of 205 t/km$^2$ / year obtained again indicates the developing nature of the ecosystem. Ominivory index was calculated as 0.33 and flows to detritus was maximum for zooplankton followed by benthos and phytoplankton. The least flows were observed for apex predators. Mean trophic transfer efficiency was 35.2%, of which 30.5% was from primary producers and 41.7% was from the detritus. In the Mandovi estuary model, higher trophic level groups had larger ecological footprints indicating that more resources were necessary to sustain their production. Mandovi Estuary is a detritus driven ecosystem as the flow of energy is more to detritus.

Mixed trophic impact routine indicated possible impact of direct and indirect interactions (including competition) in a steady-state system and benthic omnivore has negative impact on the small benthic carnivore, whereas small pelagics which forms a major feed for marine mammals has positive impact on the group. The gillnets had negative impact on the large benthic carnivores and large pelagic and the cast nets negative impact on crabs. However, benthic omnivores are not impacted by the gillnets. The study showed that there is mixed trophic interactions, susceptible to stress induced changes and could withstand unexpected external perturbations in the present stage. The immature status of the Mandovi Estuary trophic network may be explained partly by the intensive human exploitation of the estuary. The study provides some insights into the structure and development of this ecosystem.

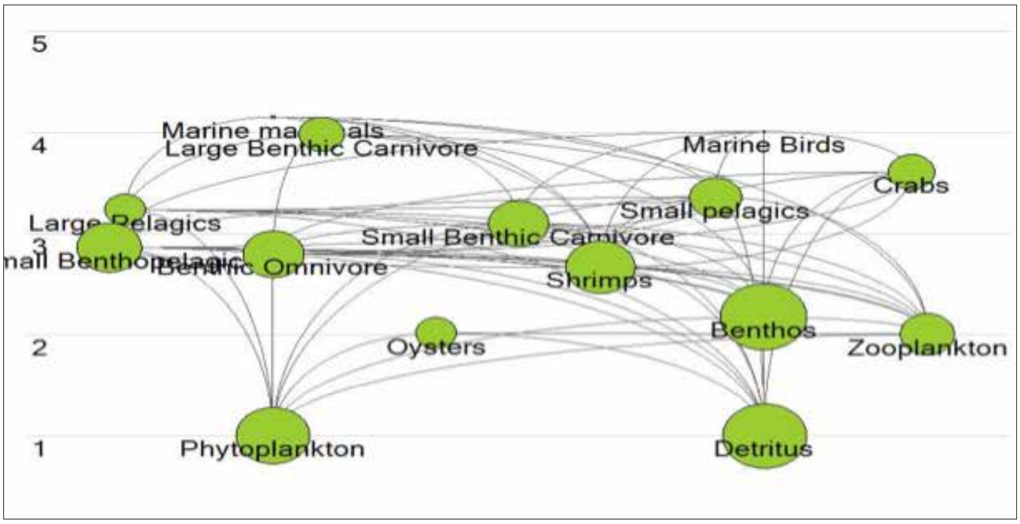


Fig 1: Flowchart of trophic interactions in the Mandovi estuarine ecosystem of Goa indicating trophic flows in tonnes km$^{-2}$, fishery catches (Circle size represent relative abundance)

# Economic impact assessment of juveniles of ribbonfish in trawl by-catch along the coast of north Andhra Pradesh

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A study was carried out to assess the economic value of juveniles of commercially important species of ribbonfish encountered in by-catch caught by multiday commercial trawlers operated off the coast of Visakhapatnam, north Andhra Pradesh from December 2013 to December 2015. The juveniles of *Trichiurus lepturus* and *Lepturacanthus savala* observed in trawl by-catch were studied. Juveniles of both species, together contributed about 52.21 % by weight to the total ribbonfish caught as trawl by-catch. Individually the percentage contribution by juveniles of *T. lepturus* and *L. savala* were 45.21% and 60.21% by weight respectively. The size distribution of juveniles of *T. lepturus* was 129.5-409.5 mm whereas, for *L. savala*, it was from 89.5-369.5 mm. Juveniles of *T. lepturus* were caught mainly during March to August whereas for *L. savala* juveniles of the maximum catch was during July and November. Based on bio-economic model, it was found that if juveniles had been allowed to grow up to length at first maturity (Lm), an estimated total annual economic gain of ₹74.67 crores with an estimated biomass gain of 8764.97 t per annum would have been achieved. The estimated total annual biomass would have increased by 3.4 times and additional revenue by 5 times would have been realized. The annual economic loss to the fishermen due to juvenile landings of *T. lepturus* and *L. savala* was estimated to be ₹40.84 crores and ₹19.80 crores respectively. The results of the present study suggested that sustainable harvest of *T. lepturus* and *L. savala* would have yielded maximum economic return to the fishers. With the involvement of stakeholders using participatory approach, management measures such as increase in cod-end mesh-size of trawls to 35 mm from the present mesh size of 10-12 mm, effort restriction and awareness campaign on catching juveniles and adult should be implemented to avoid growth overfishing.

# First report on the biology and fishery of *Sepia vecchioni* Neethiselvan & Venkataramani, 2010 from Western Bay of Bengal

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Cephalopods are one of the significant components of marine capture fisheries with unevenly distributed fisheries and landings in the world's oceans. Cephalopod landings now constitute almost 5% of the world's total fisheries production. India is one of the main suppliers of cuttlefishes in the international market in addition to Thailand, Spain, China, Argentina, Peru and Indonesia. Molluscs contributed about 6% of the total marine landings (TML) of India during 2018-19 and cuttlefish contributed about 39% of the total cephalopod landings during the same period. During 2018-19, of the top six states in India contributing to the cephalopod landings, Andhra Pradesh (AP) ranked sixth contributing 2% of the mean annual marine landings (MAML). The main species of cuttlefish exploited in Andhra coast are *Sepia pharaonis, S. aculeata, S. brevimana, S. vecchioni* and *Sepiella inermis.* About 5% of the total cuttlefish landings were contributed by *S. vecchioni* during the period 2012-18. It is commonly called as 'paper cuttlefish 'due to its fragile cuttlebone and 'dotted cuttlefish' as the dorsal mantle has white patches or dots. It was first reported from the Colachal Coast of Tamil Nadu, South India. It found to have distribution mainly in the extreme coast of India in Arabian Sea, mainly in offshore fishing grounds with the depth ranging from 70 to 100m. Its sporadic occurrences was recorded in Bay of Bengal along Northern Tamil Nadu coast in coastal waters with the depth as low as 10m. It forms commercial fishery off Kanyamumari Coast from August to November in trawlers and form sporadic fishery in the motorized traditional fishing in hook and lines along with other cuttlefish species. There are no reports on its world-wide distribution. In western Bay of Bengal it shows a seasonal fishery with maximum landings during winter.

The Length-Weight relationship showed it has a hypo-allometric growth with *'b'* value of 2.206. The sex ratio was 1:0.917 indicating a numerical dominance of males in the fishery. The mean size of the species in the fishery was about 80.37 mm. Eventhough they have a morphometric differences in sexes, there was no sex based size difference in the fishery data. Most of the specimens analysed had empty stomachs especially the males (66%). The non-empty stomachs had fishes and crustaceans like shrimps, stomatopods and small crabs. They are batch spawners which spawn throughout the year with a fecundity of 61-154 eggs.

# Fishery, length-weight relationship and relative condition factor of Dussumier's ponyfish *Karalla dussumieri* (Valenciennes, 1835) and toothpony *Gazza minuta* (Bloch, 1795) from Pamban vicinity of Gulf of Mannar, Tamil Nadu

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The fishery of silverbellies in trawl along Pamban vicinity of Gulf of Mannar have been studied along with the length-weight relationship (LWR) and relative condition factor (Kn) of two dominant ponies *Karalla dussumieri* and *Gazza minuta.* The analysis of LWR and Kn has been done based on the data obtained from 937 and 943 samples of *K. dussumieri* and *G. minuta* respectively, collected during December 2016-April 2018. The estimated total landing, monthly average catch per effort (C/E) and catch per hour (C/H) of silverbellies during 2016 were 4645.94t, 665.04kg and 50 kg respectively. The contribution of ponies to the total fish landing ranged from a minimum of 3.28% in January to a maximum of 65.85% in June ie., immediately after the trawl ban. A remarkable reduction of32.2% was observed in the silverbellies landing during 2017 than the previous year, with a total estimated catch of 3150.22t, average monthly C/E of 416.42 kg and C/H of 23.13 kg. In this year also a minimum contribution of silverbellies to the total fish landing was observed in January (3.53%) and maximum (51.68%) recorded during November. The species contributed to the silverbellies landing were *Karalla dussumieri* (43%), *K. daura* (8.3%), *Gazza minuta* (38.4%), *G. rhombea* (0.55%), *Equulites lineolatus* (3%), *E. leuciscus* (1.3%), *Deveximentum indicium* (4.1%) and *D. ruconius* (1.35%). The mechanised sector contributed maximum (95.5%), followed by motorised (4.13%) and least from non-mechanised sector (0.31%). The length-weight (LW) relationship of *K. dussumieri* and *G. minuta* was estimated using the exponential equation $W= aL^b$. The coefficients 'a' and 'b' of the LW equation were derived as 0.00002 and 2.932 for male, 0.00003 and 2.877 for female, 0.00002 and 2.919 for indeterminate (ID) *K. dussumieri* respectively representing negative allometric growth. The same parameters estimated for male, female and ID individuals of *G. minuta* were 000018566 and 2.962, 0.0000133984 and 3.034 and 0.000012145 and 3.0995 respectively indicating isometric growth pattern. The calculated relative condition factor for male, female and ID individuals of *G. minuta* were 1.01, 1.02 and 1.01 respectively. The condition of female fish found better than male and ID fishes. Similarly the Kn values of male, female and ID individuals of *K. dussumieri* are 1.01, 1.03 and 1.02 respectively. Here also females are found to have better condition than other two counterparts. The highest (1.23) and lowest (0.82) values of Kn of male *G. minuta* noticed in October and November respectively. Whereas Kn values of the female *G. minuta*, ranged from 0.78 in March to 2.7 in February. The monthly condition factor of female *K. dussumieri* varied from 1.01 in June and August to highest value of 1.11 in January 2017. A second peak of Kn (1.06) appeared in April for female simultaneous with highest Kn value of male (1.05)

# Clam fishery of Subarnarekha estuary, Balasore, Odisha and its utilization

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The Subarnarekha River, about 460 km in length, originates in the Chotanagpur plateau near Ranchi, flows through the states of Jharkhand, West Bengal and Odisha before joining the Bay of Bengal about 1.5 km downstream of Kirtania of Balasore District. The Subarnarekha Estuary is a natural bed for bivalves and supports fishery of the *Meretrix* spp. Asiatic hard clam, *Meretrix meretrix* (Linnaeus, 1758) dominates the fishery along with blood clam, *Anadara granosa* and others. The annual clam fishery from the estuary was estimated at 32,000tonnes per year. About 500 to 800 persons from more than 600 families from adjacent villages harvest these resources round the year. Both male and female fishers are engaged in collection by hand picking from shallow waters up to depth of 1 to 1.5 m. Average of 3 to 5 bags weighing 60-80 kg each are collected per day per person with a total catch weighing nearly 300 kg/day/person. The catch rate declines during post monsoon and increases with onset of winter. Small sized clams occur immediate after monsoon in August to September months. The density of clams per square meter area varied between 1.0 to 2.5 kg and the number varied between 60 to 200 in numbers.

The clams were not used for direct human consumption and the collected shells were packed in bags and left in the intertidal zone of the estuary for 7 to 10 days. During high tide the bags were opened and dead shells were washed and brought to the shore and sun dried. After drying the shell were graded to their size and packed in gunny bags. The dried shells were sold to the local middleman for ₹100 to 150 per bag depending on the size. Shell grinding mills are collecting the shells from the fishermen. The shells are pulverized to smaller particles, sieved for removing sands, packed in bags and transported to West Bengal in trucks and sold at ₹500 per bag. These powders are used as calcium supplement in avian feeds and also for calcium carbonate

production. This practice of putrefying the live bivalves increases the organic load and fouling water condition in these areas. Since clam meat can be utilized as aqua feed, the possibility of utilizing this in the nearby aqua farms as a rich source of animal protein may be explored for additional income generation support and for ameliorating environmental impact. Considering the domestic demand for clams in the southern states, the possibility of interstate transportation and marketing can also be attempted with the involvement of various stakeholders.

# Assessment of post 2018 August flood water quality of selected coastal ecosystems of Kerala, India

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Water quality assessment was done during August - September, 2018 in selected coastal marine ecosystems *viz*. lower end of estuaries, intertidal waters of beaches, mudbank region and inshore waters covering the districts of Malappuram, Thrissur, Ernakulam, Alappuzha and Kollam in Kerala, India. The surface waters were sampled to analyse selected water quality indicators using standard protocols and analytical methods (APHA 1998; USEPA, 2006).

The results revealed that, compared to the pre flood period, in the Vembanad and Ashtamudi Lakes, there were increased content of nutrients, especially the dissolved inorganic nitrogen (DIN) (Tables 1 & 2). The major share of DIN was from the content of total ammoniacal nitrogen. Total Suspended Solids (TSS) was higher in Ashtamudi Lake but not so in Vembanad Lake. In both the Lakes, the chlorophyll contents were higher compared to the pre flood period. Similar trend was seen for nutrients and chlorophyll in the samples collected from the intertidal waters. The mudbank region showed increased nutrients, chlorophyll and TSS. The nearshore regions off Kochi and off Neendakara also showed increased nutrients, chlorophyll and TSS.

Table 1. Water quality of selected stations of Ashtamudi Lake during August – September 2018

| Date | Location | SWT °C | Salinity PSU | pH | DO $mgl^{-1}$ | Chl -a | Chl -b | Chl -c | TSS | DIN | DIP | DI Si |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | $\mu g\ l^{-1}$ | | | $mg\ l^{-1}$ | | | |
| 05-09-18 | AL 1 | 29.00 | 20.00 | 7.14 | 13.24 | 4.70 | 0.31 | 0.50 | 282.60 | 0.22 | 0.05 | 1.23 |
| 05-09-18 | AL 2 | 28.50 | 21.00 | 7.14 | 13.62 | 13.24 | 0.44 | 2.51 | 123.50 | 0.24 | 0.00 | 1.16 |
| 06-09-18 | AL 3 | 24.00 | 38.00 | 7.13 | 5.24 | 23.58 | 0.00 | 5.05 | 194.60 | 0.17 | 0.01 | 0.30 |
| 06-09-18 | AL 4 | 24.50 | 35.00 | 7.15 | 5.47 | 23.34 | 0.97 | 1.02 | 195.40 | 0.11 | 0.00 | 0.31 |
| 06-09-18 | AL 5 | 24.00 | 37.00 | 7.13 | 5.84 | 18.73 | 1.17 | 12.33 | 200.30 | 0.07 | 0.01 | 0.42 |
| 06-09-18 | AL 6 | 25.00 | 36.00 | 7.12 | 5.94 | 19.00 | 0.76 | 11.46 | 206.70 | 0.18 | 0.03 | 0.53 |
| 06-09-18 | AL 7 | 24.50 | 40.00 | 7.11 | 6.07 | 22.56 | 1.00 | 13.85 | 222.30 | 0.21 | 0.05 | 0.30 |
| 06-09-18 | AL 8 | 24.50 | 38.00 | 7.10 | 4.25 | 20.51 | 0.00 | 0.00 | 174.10 | 0.28 | 0.06 | 0.34 |
| 06-09-18 | AL 9 | 26.00 | 35.00 | 7.12 | 4.68 | 10.09 | 0.09 | 4.01 | 214.60 | 0.27 | 0.05 | 0.20 |
| 06-09-18 | AL 10 | 24.00 | 36.00 | 7.10 | 4.64 | 10.85 | 1.70 | 8.28 | 184.60 | 0.28 | 0.05 | 0.16 |
| 06-09-18 | AL 11 | 24.00 | 35.00 | 7.13 | 3.02 | 9.57 | 0.83 | 6.85 | 158.50 | 0.11 | 0.03 | 0.29 |

Table 2. Water quality of selected stations of Vembanad Lake during September 2018

| Date | Location | SWT (°C) | Salinity (PSU) | pH | DO (mg $l^{-1}$) | Chl -a | Chl -b | Chl- c | TSS | DIN | DIP | DI Si |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | µg $l^{-1}$ | | | mg $l^{-1}$ | | | |
| **22-08-18** | VL 1 | 28.00 | 0.00 | 6.75 | 4.98 | 8.24 | 8.25 | 24.15 | 22.90 | 0.56 | 0.23 | 1.48 |
| **22-08-18** | VL 2 | 29.00 | 0.00 | 6.95 | 5.13 | 6.37 | 3.73 | 14.90 | 21.20 | 0.47 | 0.14 | 1.35 |
| **22-08-18** | VL 3 | 25.00 | 0.00 | 6.69 | 6.48 | 5.74 | 5.86 | 19.73 | 32.40 | 0.56 | 0.05 | 1.48 |
| **22-08-18** | VL 4 | 25.00 | 0.00 | 6.57 | 6.46 | 7.64 | 9.37 | 31.83 | 23.90 | 0.70 | 0.03 | 1.68 |
| **22-08-18** | VL 5 | 27.00 | 0.00 | 6.39 | 5.24 | 5.51 | 3.60 | 11.52 | 72.00 | 0.53 | 0.01 | 1.40 |
| **22-08-18** | VL 6 | 28.00 | 0.00 | 7.05 | 4.31 | 5.05 | 3.95 | 9.50 | 42.30 | 0.87 | 0.19 | 1.61 |
| **22-08-18** | VL 7 | 27.00 | 0.00 | 7.07 | 5.15 | 5.35 | 5.91 | 11.76 | 35.63 | 0.69 | 1.77 | 1.47 |
| **22-08-18** | VL 8 | 28.00 | 0.00 | 6.96 | 4.21 | 5.80 | 5.38 | 15.98 | 32.58 | 0.75 | 1.80 | 1.89 |
| **04-09-18** | VL 1 | 26.00 | 0.00 | 6.87 | 4.48 | 5.23 | 2.00 | 4.86 | 19.20 | 0.30 | 0.05 | 1.88 |
| **04-09-18** | VL 2 | 29.00 | 0.00 | 7.04 | 4.48 | 4.88 | 0.96 | 0.85 | 20.60 | 0.15 | 0.08 | 2.73 |
| **04-09-18** | VL 3 | 28.00 | 0.00 | 6.96 | 3.95 | 20.14 | 6.22 | 17.37 | 36.00 | 0.95 | 0.13 | 2.51 |
| **04-09-18** | VL 4 | 27.00 | 0.00 | 7.07 | 7.25 | 3.46 | 1.72 | 3.28 | 27.00 | 0.77 | 0.01 | 2.27 |
| **04-09-18** | VL 5 | 28.00 | 0.00 | 6.85 | 7.70 | 15.03 | 2.92 | 9.41 | 58.00 | 0.43 | 0.01 | 2.16 |
| **04-09-18** | VL 6 | 26.00 | 0.00 | 6.88 | 7.02 | 3.69 | 1.81 | 0.99 | 30.00 | 0.67 | 0.01 | 1.98 |
| **04-09-18** | VL 7 | 28.00 | 4.00 | 6.82 | 6.72 | 5.90 | 2.15 | 4.26 | 32.00 | 0.43 | 0.01 | 1.77 |
| **04-09-18** | VL 8 | 31.00 | 0.00 | 6.88 | 8.09 | 9.34 | 4.52 | 2.91 | 31.20 | 0.01 | 0.07 | 1.49 |

# Analysis of bycatches from mid-water trawl fishery for ribbonfish *Trichiurus lepturus* in north-west coast of India

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Ribbonfish is one of the major marine resources in the seas around India with predominance in the north-west coast. The mid-water trawl fishery in north-west coast of India targets adult ribbonfish, principally the large head hairtail (*Trichiurus lepturus*). Trawl, a relatively non-selective gear is known for the by-catches, especially the juveniles and sensitive species. The trawl based ribbonfish fisheries was subject to an investigation on the by-catches based on data collected during February 2018-February 2019 from selected fishing vessels operated from Veraval fishing harbour. The main objective of the study was to bring forth the dynamics of catches over space and time and suggest management actions to deal if there are any concerns. In all, data from 518 trawling operations were observed with the help of the skippers of the identified trawlers. Unsorted catch samples were provided by the skipper with details of position and time of fishing after every voyage. Ribbon fish was the single most important resource accounting for 46.74% of the catch. The remaining 53.36% was constituted by 117 species with dominance of teleosts (63.87%) followed by cephalopods (33.75%), elasmobranchs (0.59%) and crustacean (1.79%). Bycatch species with the highest annual average catches were *Uroteuthis duvaucelii, Nemipterus japonicus, Johnius glaucus, Sepia elliptica, S. pharaonis* and *Priacanthus hamrur.* These species together contributed nearly 49% of the total bycatch. The bycatch per hour of fishing differ significantly between seasons with the lowest during summer and the highest during post-monsoon. Quantity of bycatch was lower in the offshore waters than inshore waters. CITES as well as IUCN listed animals observed were *Chelonia mydas, Sphyrna lewini* and *Alopias* spp. The study revealed that bycatch was relatively higher than those reported for similar mid-water trawlers operating in other parts of the world and suggests to monitor the fishery in north-west coast of India more closely and device pragmatic mitigation measures to reduce the bycatch.

# Trophic studies of smooth blassop *Lagocephalus inermis* from south eastern Arabian Sea with emphasis on its ontogenetic and seasonal variations

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In this work the food and feeding of smooth blaasop, *Lagocephalus inermis,* were studied during 2016-2018. *L. inermis* has emerged as a fishery resource from south eastern Arabian Sea since 2007 and is considered to be the result of trophic cascading happening in Arabian Sea. The objective of the study was to collect detailed information on the diet composition and its seasonal and ontogenetic variations. Seasonal feeding intensity was assessed using Vacuity and Repletion Index (VI and RI) and Full stomach ratio (FSR). To quantitatively express the importance of different prey in the diet Index of Relative Importance (IRI) was used. Diet composition and trophic level of prey items was used to estimate the trophic level of the species and dimensionless Omnivory Index (OI). The square root of OI is the standard error of the trophic level and a measure ofthe uncertainty about its precision due to both omnivory and sampling variability. To evaluate niche breadth, the Shannon diversity index (H) was used. In order to identify shifts in the diet composition with size, clustering (group average) and ordination (non-metric multidimensional

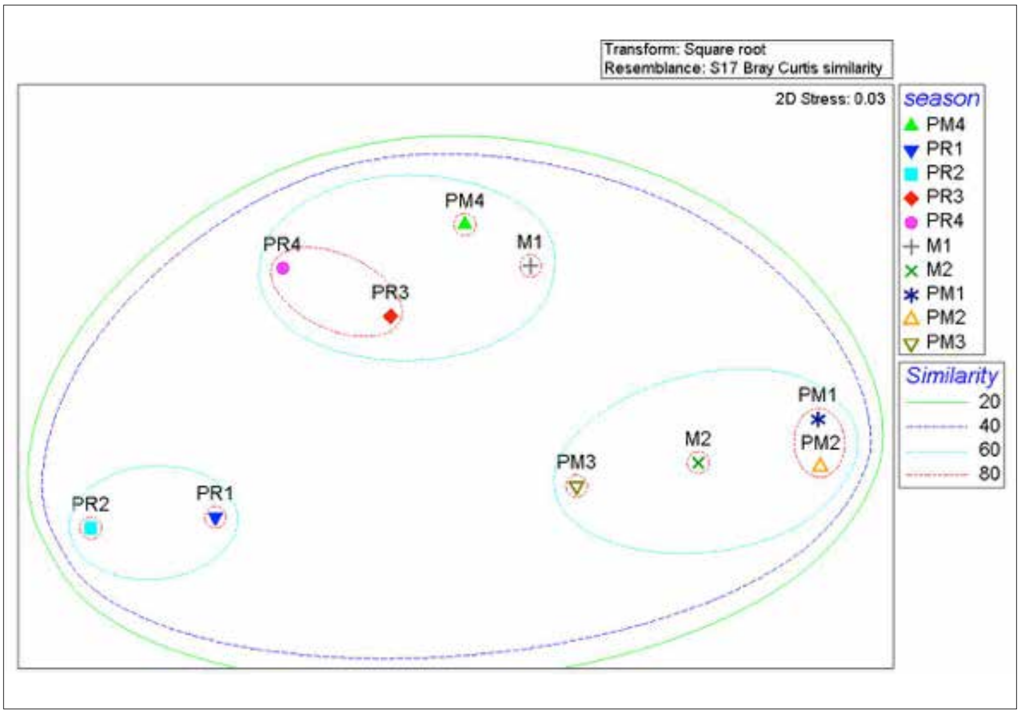


Fig. 1: Multi-dimensional scaling ordination for prey dissimilarity between seasons

scaling) techniques were performed on prey numerical/weight abundance using the PRIMER algorithms and both methods were based on the Bray & Curtis Similarity Index performed on standardized data.

A total of 1,625 stomachs of *L. inermis* were studied during the period. Results of the study shows that *L. inermis* is a benthic predator feeding mainly on cephalopods (IRI % 53) followed by crustaceans (35 %) and fishes (12 %). The VI percentage of empty stomach show monthly variations. The VI was 66% in March which decreased to 15% in August. More of piscivorous diet was observed in March whereas the diet was dominated by cephalopods in August. Repletion index which reflects the frequency of feeding ranged from 1.6 to 3.3, highest observed in February and December and lowest in March. Twenty-six types of prey were identified in the stomach content. Major prey items were constituted by *Loligo* spp. and crabs followed by *Saurida* spp. In both adult and juvenile stages, cephalopods was the dominant food whereas juveniles were feeding exclusively on cephalopods and crabs and as the fish grows the diet shifted to fishes also. The repletion index ranged from 1.6 to 3.3 which indicated feeding intensity. High feeding intensity was observed in February and December due to the abundance of the feed in the Sea and lowest was seen in March. FSR ranged from 7.0 to 23.0 with highest in March. Diet breadth of *L. inermis* was 2.42. The estimated TROPH value was 4.5 (SE=0.61) and the OI was 0.37, indicating voracious carnivorous feeding on wide variety of prey items. Trophic value is found to be high as it feeds on fishes of higher trophic level. Seasonal analysis of diet using cluster analysis showed that maximum similarity was between pre-monsoon and post-monsoon to which monsoon got linked. Four clusters were also observed for the monthly analysis. Non-metric multidimensional scaling, delineating the different months and season gave essentially the same picture like dendrogram. SIMPER analysis showed that major prey items contributing to the dissimilarity between pre-monsoon, post-monsoon and monsoon was *Saurida* spp. and crabs, while prawn and *Apogon* spp. contributed to the dissimilarity between monsoon and post-monsoon.

Present study shows that *L. inermis* is a benthic carnivore, feeding mainly on cephalopods. There is shift in diet to teleost in the adult stages and occupies one of the highest trophic level in the ecosystem. Present trophic analysis of *L. inermis* will be useful in ecosystem approach to fishery management, where multi species assessment is required and will contribute to a better understanding of the trophic flow in the region. This study along with trophic studies for other species in the area would help in moving closer to an ecosystem approach to fisheries management.

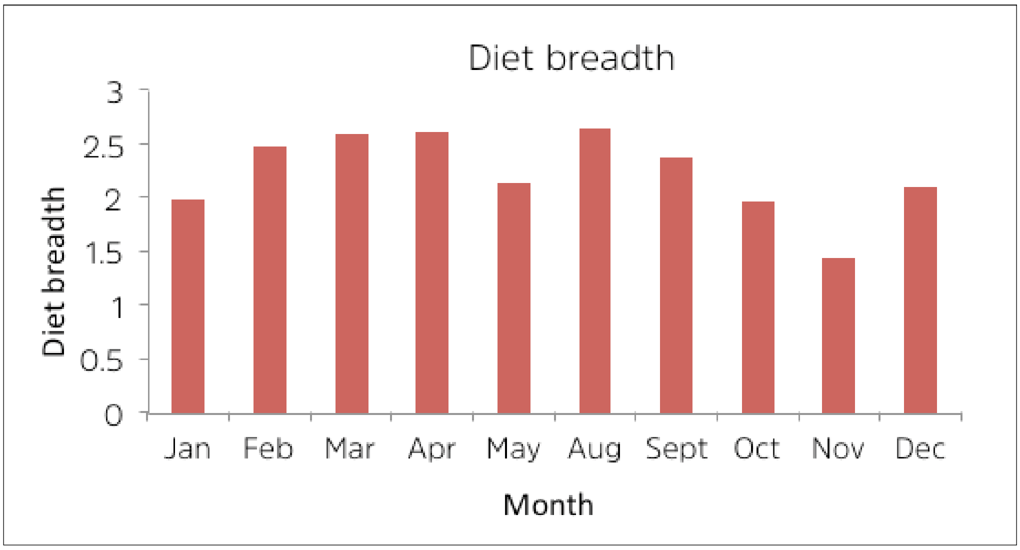


Fig. 2: Monthly variations in diet breadth of *L. inermis*

# Some biological aspects and population dynamics of the humpback redsnapper, *Lutjanus gibbus* (Family: Lutjanidae) from northern Arabian Sea

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*Lutjanus gibbus* is an important demersal species of reef-associated species of fish which is widespread in the Indo-West Pacific upto depths of 150 m. It is said to form spawning aggregations and is the major constituent of the commercial constituent of the snapper landings of the Cochin Fisheries harbour, Kerala. A proper understanding of the biology and dynamics of fish is very necessary for the future management of the fisheries and exploitation of the fish stock. Though the biology and dynamics of snappers have been studied in different localities information on the tropical species especially from Indian ocean is lacking. The present study aims to evaluate some biological aspects as well as the fishery of this species. A concerted effort was attempted to observe the landings and changes in the fishery in Kerala during the period 2012 -2016.

The specimens were collected from Cochin Fisheries Harbour on a biweekly basis during the period from April 2012 to March 2016. The size (TL, total length; SL, standard length) were measured and weighted (BW, total body wet weight). A total of 690 individuals in the length range of 165-455 mm were studied during the period. The fish was landed throughout the year except during the fishery ban period of July and August contributing about 6 to 12 percent of the total snapper landings during the study period. The main spawning season was estimated as between February - June with spent females occurring in May and June. Recruitment into the fishery was observed during September and October.

Males and females were analysed separately as well as merged for length weight relationship. The von Bertalanffy growth parameters were estimated as follows: $L_\infty$ =477.8 mm, K =0.3, which was much higher compared to that reported from Okinawa waters ($L_\infty$=390.5 mm, K= 0.210 year$^{-1}$). Natural mortality M was estimated at 0.7. The values of total mortality coefficient Z for *L. gibbus* was estimated from the length converted catch curve of Pauly (1983) at 1.42 yr$^{-1}$ respectively. Accordingly, the exploitation rate which is an indication to the state of the stock was estimated at 0.52 using the parameters fishing mortality F and Z. The current exploitation level is an optimum one (Eopt = 0.5 as given by Gulland, 1971 and Eopt = 0.4 that given by Pauly, 1984).

*Lutjanus gibbus* is an excellent food fish and an important item of export under the trade name Red snapper from Kerala. Though there are ciguatera reports from snappers, from other countries, there are no such reports from Indian waters thereby increasing to the food value of these fishes. With importance being given to seafood protein, exploitation of these resources can boost seafood production.

| Sex | a | b | Rsqr |
|---|---|---|---|
| Males | 2.2E-05 | 2.922 | 0.981 |
| Females | 4.4E-05 | 2.789 | 0.8 |
| Pooled | 2.6 E-05 | 2.8919 | 0.91 |

# Reproduction and feeding in *Penaeus indicus* (H. Milne Edwards) (Crustacea: Decapoda: Penaeidae) off Arabian Sea, India

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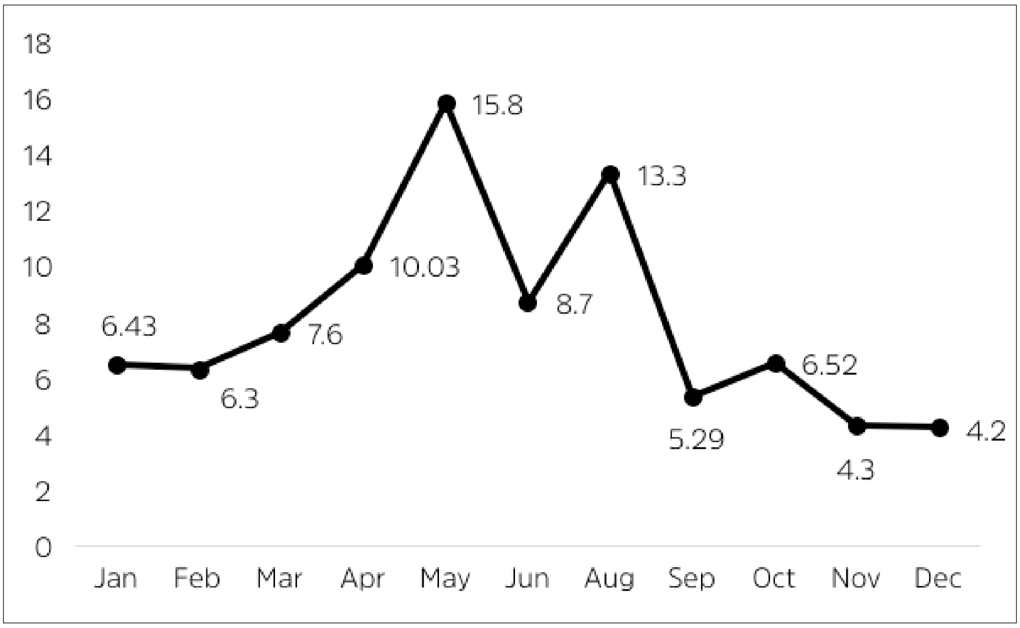
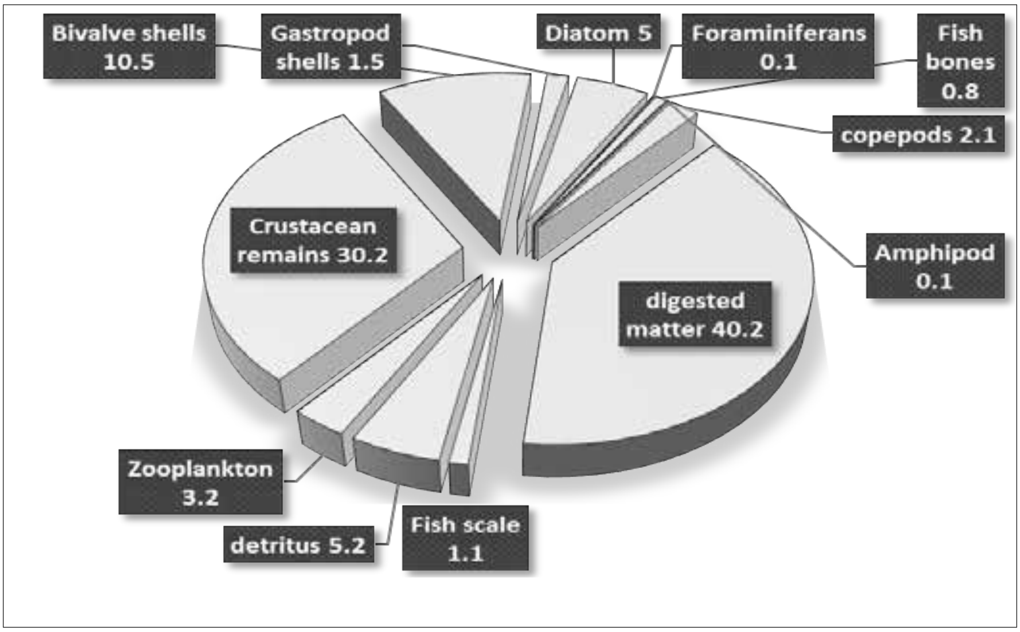
The present study aims to estimate the gonadosomatic index, fecundity, spawning peaks, feeding intensity and index of preponderance of the dietary items of *Penaeus indicus* from Kerala, southwest coast of India. Specimens of *Penaeus indicus* were monthly sampled during September 2017 to October 2019 from Munambam Fisheries Harbour (10°18'N, 76°17'E) in Kerala, for the study. The gonado-somatic index for females were calculated by the equation GSI = (GW/BW) X 100. It ranged from 4.2 to 15.8, highest in May and least in December. Fecundity estimates ranged from 31,913 to 2,44,285 eggs for body length range 128 to 195 mm. The reproductive period was apparently continuous, the monthly values of the gonadosomatic index indicated that spawning occurred in two peaks - one during May and another peak during August.

Stomach content in majority of the specimens examined were in digested state (40.2%) and among the food items analysed the most preferred prey was crustaceans (30.2%) followed by bivalve shells (10.5%). Dietary comparison between the sexes did not show any difference. Information generated in this study can be used as input in models that can assess the impact of the fishery on reproductive output, besides better understanding of the biology of the species and its role in the marine ecosystem.




Monthly GSI values for female of *P. indicus*




Food composition - pooled *P. indicus*

# Offshore gillnet fishing off Andhra Pradesh in the western Bay of Bengal

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Offshore gillnet fishing using mechanized crafts off north Andhra Pradesh along western Bay of Bengal is a recent phenomenon. Mechanized fishing crafts of 18 m OAL are used in the fishery; however the gillnets are set by the fishermen manually. The gillnets used for offshore fishing measure up to 5 km in length with mesh sizes of 150 mm. These nets are operated in areas beyond 200 m depth to almost the edge of the Indian EEZ in the Bay of Bengal. Fishing is conducted throughout the year and the main targets are tunas (skipjack and yellowfin) along with other large pelagic and demersal fish. We collected catch data along with fishing positions from a gillnet fisherman during 2018-2019 and analyzed the species composition and spatio-temporal dynamics of the catch. During 2018-19, catch of an individual gillnet set varied from 31.5-3551 kg with an average catch of 713 kg (SE ±62.6). The catch was dominated by *Katsuwonus pelamis* (skipjack tuna, 63.0%), followed by *Thunnus albacares* (yellowfin tuna, 22.1%), *Euthynnus affinis* (little tunny, 3.6%), *Xiphias* spp. (swordfish, 2.3%) and *Istiophorus* spp. (sailfish, 2.0%). The highest average monthly catch was observed in January (1349 kg) and December (1221 kg). Skipjack tuna registered highest catches in December - January with an average monthly catch of 1076 kg during these two months. Yellowfin tuna on the other hand had the highest catch during June-August with an average monthly catch of 384 kg during these 3 months. The swordfish catch had two peaks, one during July and the other in December. The other species caught in these nets were dolphinfish, carcharhinid sharks and devil rays. The highest catch of skipjack tuna was found south of Visakhapatnam in areas where depth exceeded 1000m. Yellowfin tuna on the other hand were caught mainly near the 200m depth contour in areas north of Visakhapatnam.

# A preliminary study on the length weight relationship of *Parapersis alboguttata* harvested off Colachel coast

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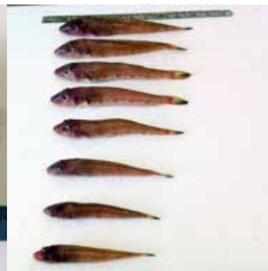
Bluenose sandperch (*Parapersis alboguttata)* is one of the demersal fishes classified under the family Pinguipedidae (Order: Perciformes). *Parapercis alboguttata* was first recorded from south west coast and later from Bombay waters. The sandperches of the Genus *Parapersis*are group of bottom fishes of tropical and sub-tropical region usually associated with shallow loagoons and reef areas. An incidental catch of about 400 kg recorded from Colachel landing centre. A total of 262 specimens examined for this study. The depth of operation was about 50 metres. The distribution of *P. alboguttata* observed up to 70 m depth in the continental shelf. The relationship between length and weight of *P. alboguttata* evaluated using the equation Log w = -6.5058+ 2.82040 Log L (r = 0.9477) and its exponential form is W =0.001495 $L^{2.82040.}$ negatively allometric growth found for the samples and the Fulton's condition factor values showed no significant variations (P<0.001) for small samples (less than 100 mm) and vice versa for comparatively larger specimens. Even if it appear as a by-catch in trawl fisheries, *P. alboguttata* has a good domestic market off Kanyakumari coast, especially Muttom and Colachel.





# Preliminary study on the fishery and biology of smoothback guitarfish, *Rhinobatos lionotus* Norman, 1926 along West Bengal coast

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The guitar fish resource of West Bengal comprises of four species namely *Glaucostegus granulatus, Rhinobatos linotus, Rhinobatos annadalei* and *Glaucostegus obtusus*. The landings of guitar fishes is mainly dominated by *G. glaucostegus* (57.31 %) followed by *R. linotus* (42.68 %) during 2018. *Rhinobatos linotus* (smoothback guitar fihes) is an extant of West Bengal and landed frequently in Digha Mohana fish landing centre though it was observed to be abundant during August, 2018 to October, 2018. The guitar fishes were exploited maximum by multi day trawls (91%) followed by mechanized gill netters (9%) operated southwards from Digha in the Bay of Bengal. The species has been assessed as 'Data deficient due to lack of data on its biology and population. Hence an attempt was made to reflect some information on its fishery and biology along its native region. A total of 160 samples were collected from Digha Mohana fish landing centre, West Bengal (India) from January, 2018 to December, 2018. The smoothback guitar fishes landed were found to be in a length range of 33.2-66.4 cm (TL) with a mean size of 46.9 cm and weighing 122-868 g with a mean weight of 362.67g. Both the males and females were found to be mature throughout the year. The percentages of immature, mature, gravid and spent individuals were 1.25 %, 68.7 %, 28.13 % and 1.88 % respectively. The sex ratio was found out to be 1:1.5 (F:M) showing the dominance of males in the fishery. The number of pups varied from 2-7 with a length range of 5.1-14.8 cm (TL). The mean size of the pups was found to be 10.7 cm. The length of full term pups ready to be born were found to be in a range of 14.3-14.8cm (TL) during the month of October to November, which may be considered as the length at birth and parturition season respectively for the species. Length at 50% maturity of the females and males were 48.5 cm and 40.2 cm respectively. The species is an ovoviviparous with embryos feeding initially on yolk, then getting additional nourishment from the mother. Diet studies indicated that the species preferably feeds on variety of shrimps, unicorn cod, squids and crabs.

# Probabale trawl fishing grounds in Indian EEZ: a passive georeferencing approach

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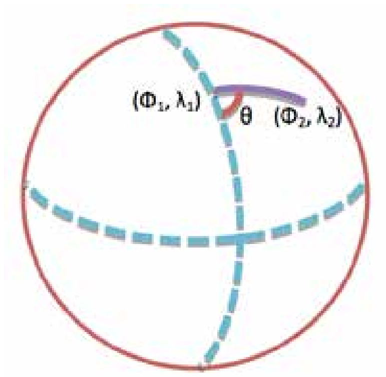
In India, marine fishery sector provides direct employment to one million people and indirectly supports another half a million people through allied activities. So protecting fishery resources through sustainable harvest is utmost important for the sustainable livelihood of coastal fishers. To this end, assessment of the availability of the marine resources will be helpful in deriving management plans by ensuring the sustainable harvest of the resources. Geographic Information System (GIS) tools are very useful in fishery management for mapping of habitats, georeferencing information on catch and effort and linking catch with the oceanographic and biochemical factors. This is possible when the resource habitat information is available on a spatial scale. In India, landing centre based surveys are commonly practised to make an assessment of resources, as the exploratory fishery resources surveys are much time consuming and expensive. In such surveys, lack of geo-tagging of the resources observed at landing centre makes it difficult for the mapping of the habitat. Usually the landings record have information about bearing and the distance covered by the craft surveyed and using the following Haversine formula, for finding the destination coordinates given distance and bearing from start point coordinates, probable latitude and longitude of the fishing grounds can be obtained:

$$\phi_2 = \text{asin}\left( \sin\phi_1 \cdot \cos\delta + \cos\phi_1 \cdot \sin\delta \cdot \cos\theta \right)$$

$$\lambda_2 = \lambda_1 + \text{atan2}\left(\sin\theta \cdot \sin\delta \cdot \cos\phi_1, \cos\delta - \sin\phi_1 \cdot \sin\phi_2\right)$$




Where $\phi$ is latitude, $\lambda$ is longitude, $\theta$ is the bearing (clockwise from north), $\delta$is the angular distance d/R; d being the distance to destination, R the earth's radius (mean radius = 6,371km), 'asin'is arcsine (i.e. the inverse sine) of a given number and 'atan2' is the arctangent (or inverse tangent) of the specified x- and y-coordinates.

In this paper, attempt has been made to find the probable trawl fishing grounds (spatial coordinates) using information on bearing and distance from landing centre of trawlers operated in the Indian Exclusive Economic Zone (EEZ) during the year 2018. This has been done separately for single day trawl net (MTN) and multiday trawl net (MDTN) and presented in Fig. 1.

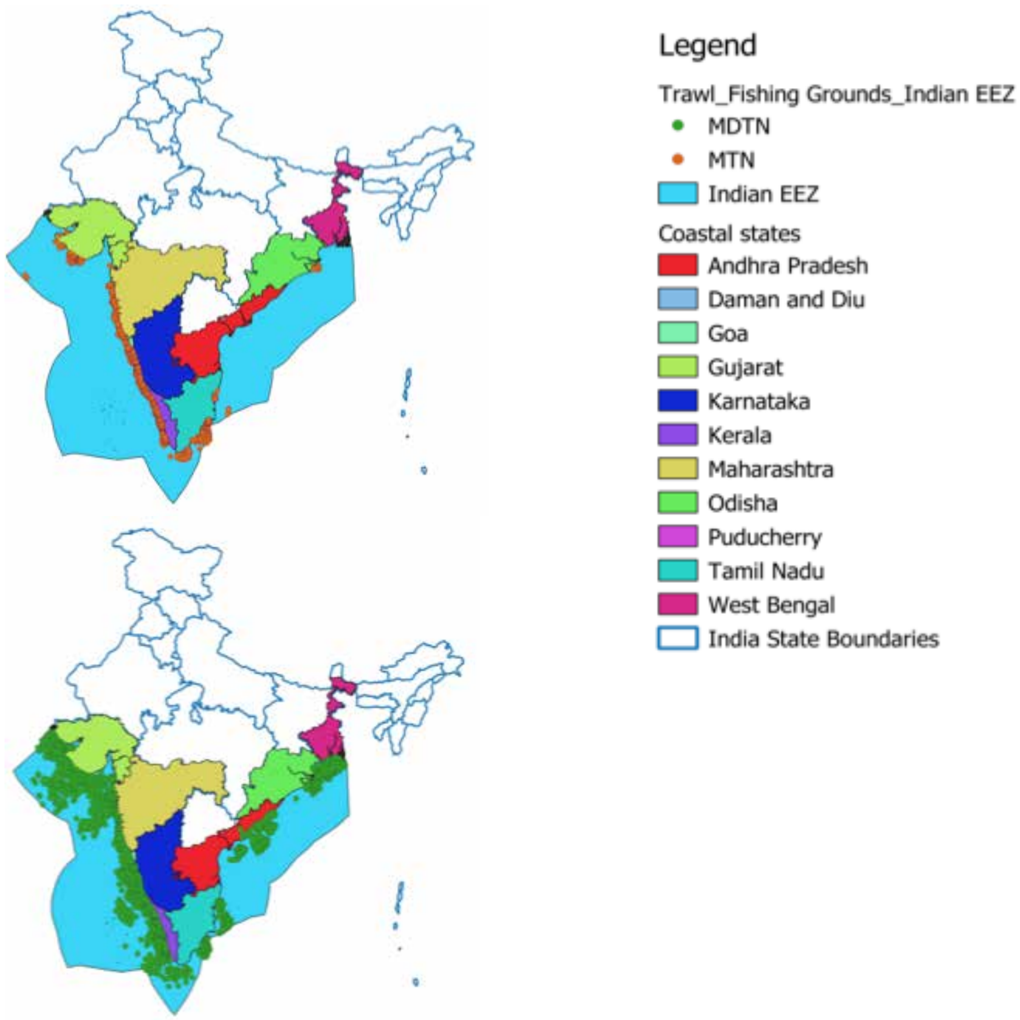



Fig. 1: Probable trawl fishing grounds in Indian EEZ during the year 2018

# Biological indices for developing fishery predictors- A case study on Indian Oil sardine

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Length-weight relationships in fish have two main applications in fish stock assessments. Firstly, they can be used to convert catch statistics to numbers or weight as the case may be and secondly to develop Condition Factors that have important bearing on stock abundance through the maternal condition-fecundity-recruitment loop in fishes. The Indian oil sardine (IOS) is a major fishery especially along the southwest coast of India and shows sharp responses to environmental phenomena such as *El Nino* that affects its feeding and reproductive cycles. The fishery along the Kerala coast which was highly erratic during the past decade exhibited a generally declining trend and loss of livelihood for several fishermen.

In this scenario, for exploring the possibility of making fishery forecasts, analysis of the trends of Condition Factor, Length-Weight relationships and fecundity of oil sardine sampled from the ring seine landings during the period 2002 -2018 off Cochin, Kerala was done. The results were also compared to published data for earlier years. The condition factor of female spawners was <3 during 2002, 2004 -2005 and since 2014 which is continuing. Incidentally these were also the periods of sharp environmental disturbances globally, caused by the *El Nino* and associated with trend of low sardine landings. The relative fecundity of IOS which ranged between 600-900 eggs/g body weight during the 60s was as low as 200 in 2014. Multivariate Analysis of Variance was performed to test length -weight and condition factor of oil sardine over the years. There are significant differences in the annual means (Pillai's trace = 0.802, Wilks's lambda = 0.306 both test statistics were highly significant p <0.001) which indicate that these biological indices can be used for developing further as fishery predictors and incorporation in fishery management advisories.

# Diet of Indian Oil sardine *Sardinella longiceps* along Chennai coast

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The Indian oil sardine *Sardinella longiceps* forms the largest single species fishery in India. The oil sardine occurred only sporadically and was sparsely distributed along the east coast of India before the mid-1980s. Until then, massive fishery existed for oil sardine along the southwest coast of India only. Following seawater warming, the abundance increased from the year 1986 and the fishery started on a small scale, proliferated since then and emerged as the single largest fishery along the Tamil Nadu coast including Chennai. In spite of this important event in the fisheries along the Tamil Nadu coast, there is no major study on the biological characteristics of the oil sardine in its new territory, where it has established populations.

With this objective, the diet of the Indian oil sardine, *Sardinella longiceps* was studied along Chennai coast. Data on key trophic attributes were collected with reference to two variables, namely, body size (small, medium and large) and seasons, namely (post-northeast monsoon (PNE); summer (SUM); southwest monsoon (SW) and northeast monsoon (NE) and analysed by adopting standard methodologies.

The results on trophic morphology of the fish are as follows: jaw length contributed 9.3% to the total fish length; mouth gape area: 130.7 mm$^2$; minute teeth; maximum body depth-total length ratio: 1:5.6; gill rakers in lower arch: 306; relative stomach length (RSL; stomach length/ fish length): 0.25; and relative intestine length (RIL) (measured from the junction of pyloric caeca up to the rectum): 1.87. Empty stomach contributed 7.7% to the samples. Gut content analysis showed that, feeding intensity was high during NE & PNE. They fed on prey belonging to 23 Orders and > 30 genera. The fish is a pelagic planktivore.

Different Orders of phytoplankton, especially diatoms were dominant in the stomach. Thalassiosirales in terms of frequency of occurrence and Bacillariales in terms of abundance were dominant. Protozoans and zooplankton were found in a few stomachs. Higher prey diversity was noticed in the large size group, which has the capacity to filter small-sized phytoplankton. Seasonal differences were also noticed in diet composition. Prey Specific Abundance (PSA) of Bacillariales increased to about 70% with the size of the fish and PSA of zooplankton reduced with the ontogenetic development. The narrow niche breadth of 0.11 showed the selective nature of the fish to feed on phytoplankton. Cluster analysis showed that the diet of small size group was different from the medium and large size groups. The median values of diversity indices also showed wide variations in prey diversity between size groups and between seasons.

Earlier publications have showed that the oil sardine along the southwest coast is basically a plankton feeder with diatoms, dinoflagellates and zooplankton appearing in the diet in decreasing order of abundance. The major difference between the diets of the oil sardine occurring along the two coasts is the difference in the composition of plankton species, which indicates that the oil sardine has the capacity to adapt and feed on the type of available plankton. The feeding intensity of adult and juvenile population of oil sardine varied during different seasons along the southwest whereas no such variation was noticed along southeast coast. The present study has demonstrated the capacity of the oil sardine to change its diet in relation to body size, seasons and locations.

# Standardisation of fishing effort: A modelling approach

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In India, the marine fishery is of complex multi-gear and multi-species nature where in each species is caught by a number of fishing gears and each gear harvest a number of species making it difficult to obtain a valid estimate of the fishing effort corresponding to each fish species. Hence, it becomes difficult to make assessment of fish stocks through models that require catch and catch rates as input since it is difficult to get the effort expended for each species. Since the efficiency of the gears varies, the effort made to catch a resource cannot be considered as the sum of efforts expended by different fishing gears, without first applying effort adjustment to increase its comparability. Therefore, obtaining resource wise fishing effort is a challenge and hence, it demands some measure of effort standardisation for making use in stock assessment models. The method usually adopted for effort standardisation is simply to decompose the fishing effort of each gear based on catch proportions of different species and aggregate these values for each species. There attempts made by several authors on this issue to derive a measure of Catch Per Unit Effort (CPUE) for a species in multi-species and multi-gear scenario to obtain the fishery reference points using biomass dynamics models. Here, we propose an approach for deriving and use standardized fishing effort in multi-species and multi-gear situation by incorporating additional gear standardization parameters in a modified version of biomass dynamics model for assessment of fish stocks. The mathematical expression of the modified version of biomass dynamics model for a species in multi-gear situation used in the study is

$$B_{sp,t+1} = B_{sp,t} + r_{sp}\, B_{sp,t}\left[1-\left(\frac{B_{sp,t}}{K_{sp}}\right)^{\mu_{sp}}\right] - \sum_{gr}\left(\lambda_{sp,gr}\, p_{sp,gr,t}\, E_{gr,t}\right) q_{sp} B_{sp,t}$$

*Bsp, t* is the biomass of the species *sp* in year *t*, *rsp* is the intrinsic growth rate for the species, *Ksp* is the carrying capacity for the species, *µsp* is the shape parameter for the species, l*sp,gr* is the fishing gear effort standardization parameter for the species corresponding to the gear *gr*, *qsp* is the catchability coefficient and *psp,gr,t* is the proportion of the species in the catch by gear in year *t*. In order to demonstrate the adopted method, estimated landings (in tonnes) of oil sardine (*Sardinella longiceps*) along Kerala coast and the fishing effort expended (in hours of operation) by various gears during 1997 to 2016 have been used for model building. Landings of oil sardine have been reported from mechanized trawlnets (including multiday trawlnets), mechanized purseseine, outboard bagseine, outboard gillnets, outboard ringseines, outboard trawlnets and non-mechanized gears.

The model parameters including effort standardization parameters ($\lambda$'s for each gear) has been estimated using the Maximum Likelihood estimation procedure and it was carried out by coding in Automatic Differentiation Model Builder (ADMB) environment. Results indicated a good fit and showed the level of exportation of the resources over years in comparison to the estimated MSY as shown in Fig. 1.

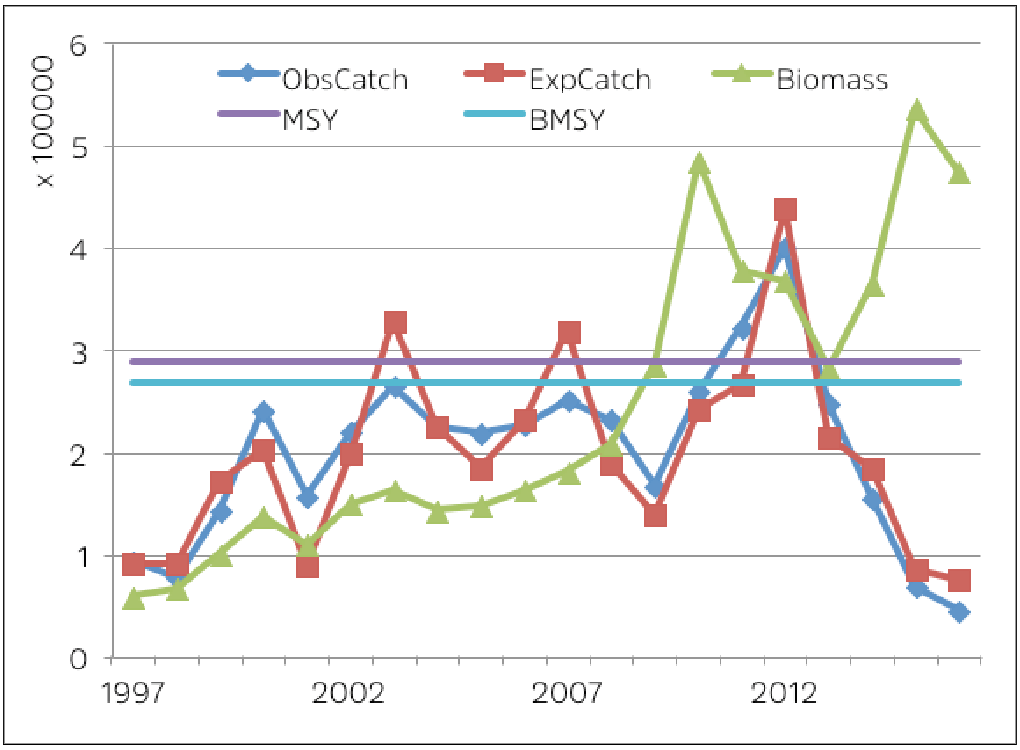


Fig.1: Observed and model predicted harvest and biomass of oil sardine during 1997-2016

# A rare occurrence of filefish *Acreichthys tomentosus* and other fishes in seagrass meadows of Gulf of Mannar

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The seagrass meadows of Gulf of Mannar (GOM) support good fishery and many fishers in the coastal villages depends on the resources. Seagrass meadows act as shelter and nursery habitat for many seagrass associated invertebrates and fishes. Artisanal fishermen are very much depend on seagrass ecosystem for their livelihood. Major fishing activities like shore seine/ beach cast fishing, gillnet fishing, squid fishing, trap fishing. *Adappuvalai*, *Nanduvalai*, *mural valai* are mainly operated in seagrass beds which sustained good fishery. Studies on seagrass associated animals and seagrass dependent fishes in Indian seagrass beds are very limited. Therefore, extensive underwater surveys were carried out in the seagrass ecosystem of GOM during the years 2016 to 2018. The fishes inhabited in seagrass ecosystem of GOM were observed during the underwater survey and photographed. Fishes were also collected from various gears operated in seagrass beds. There are about 108 species of fishes belongs to 28 genera observed and listed (Table-1)

During the underwater survey in seagrass beds of Kilakkarai coast of Gulf of Mannar, a rare filefish *Acreichthys tomentosus* (Linnaeus, 1758) was observed in inshore waters at a depth of 1 meter. Filefish also known as 'Matted

Table 1. Fishes observed in seagrass meadows of Gulf of Mannar

| | |
|---|---|
| *Ablennes hians* (Valenciennes, 1846) | *Johnius carutta* Bloch, 1793 |
| *Arothron hispidus* (Linnaeus, 1758) | *Leiognathus brevirostris* (Valenciennes, 1835) |
| *Arothron reticularis* (Bloch & Schneider,1801) | *Triacanthus biaculeatus* (Bloch, 1786) |
| *Caranx carangus* (Bloch, 1793) | *Leiognathus jonesi* James, 1971 |
| *Caranx ignobilis* (Forsskål, 1775) | *Lethrinus harak* (Forsskål, 1775) |
| *Caranx lugubris* Poey, 1860 | *Lethrinus lentjan* (Lacepède, 1802) |
| *Caranx sexfasciatus* Quoy & Gaimard, 1825 | *Lethrinus mahsena* (Forsskål, 1775) |
| *Cynoglossus macrolepidotus* | *Lethrinus microdon* Valenciennes, 1830 |
| *Decapterus kurroides* Bleeker, 1855 | *Lethrinus nebulosus* (Forsskål, 1775) |
| *Decapterus macarellus* Cuvier, 1833 | *Lethrinus ornatus* Valenciennes, 1830 |
| *Decapterus russelli* (Rüppell, 1830) | *Lethrinus reticulates* Valenciennes, 1830 |
| *Hemirhamphus far* (Forsskål, 1775) | *Lethrinus variegates* Valenciennes, 1846 |
| *Gerres abbreviates* Bleeker, 1850 | *Mugil cephalus* Linnaeus, 1758 |
| *Gerres filamentosus* Cuvier, 1829 | *Pelates quadrilineatus* (Bloch, 1790) |
| *Hemirhamphus lutkei* Valenciennes, 1847 | *Pellona dayi* Wongratana, 1983 |
| *Hemirhamphus marginatus* (Forsskål, 1775) | *Pellona ditchela* Valenciennes, 1847 |
| *Hemirhamphus quoyi* (Valenciennes, 1847) | *Pellona flavipinnis* (Valenciennes, 1837) |
| *Hemirhamphus robustus* Günther, 1866 | *Platybelone argalus* (Lesueur, 1821) |
| *Hilsa keele* (Cuvier, 1829) | *Plectorhinchus nigrus* (Cuvier, 1830) |

| | |
|---|---|
| *Polynemus indicus* (Shaw, 1804) | *Sphyraena obtusata* Cuvier, 1829 |
| *Polynemus paradiseus* Linnaeus, 1758 | *Sphyraena obtusata* Cuvier, 1829 |
| *Polynemus plebius* (Broussonet, 1782) | *Stolephorus commersonnii* Lacepède, 1803 |
| *Polynemus sextarius* Bloch & Schneider, 1801 | *Stolephorus dubiosus* Wongratana, 1983 |
| *Sardinella gibbosa* (Bleeker, 1849) | *Stolephorus indicus* (van Hasselt, 1823) |
| *Sardinella longiceps* Valenciennes, 1847 | *Strongylura leiura* (Bleeker, 1850) |
| *Scatophagus argus* (Linnaeus, 1766) | *Strongylura strongylura* (van Hasselt, 1823) |
| *Brevitrygon imbricata* (Bloch & Schneider, 1801) | *Terapon jarbua* (Forsskål, 1775) |
| *Selaroides leptolepis* (Cuvier, 1833) | *Terapon puta* Cuvier, 1829 |
| *Siganus argenteus* (Quoy&Gaimard, 1825) | *Terapon theraps* Cuvier, 1829 |
| *Siganus canaliculatus* (Park, 1797) | *Thryssa dussumieri* (Valenciennes, 1848) |
| *Siganus corrallinus* (Valenciennes, 1835) | *Thryssa hamiltonii* (Gray, 1835) |
| *Siganus javus* (Linnaeus, 1766) | *Thryssa malabarica* (Bloch, 1795) |
| *Siganus lineatus* (Valenciennes, 1825) | *Thryssa mystax* (Bloch & Schneider, 1801) |
| *Siganus luridis* (Rüppell, 1829) | *Thryssa purava* (Hamilton, 1822) |
| *Siganus puellus* (Schlegel, 1852) | *Thryssa setirostris* (Broussonet, 1782) |
| *Siganus punctatus* (Schneider & Foster, 1801) | *Upeneus luzonius* Jordan & Seale, 1907 |
| *Siganus spinus* (Linnaeus, 1758) | *Upeneus moluccensis* (Bleeker, 1855) |
| *Siganus stellatus* (Forsskål, 1775) | *Upeneus sulphureus* Cuvier, 1829 |
| *Siganus vermiculatus* (Valenciennes, 1835) | *Upeneus sundaicus* (Bleeker, 1855) |
| *Sphyraena barracuda* (Edwards, 1771) | *Upeneus taeniopterus* Cuvier, 1829 |
| *Sphyraena forsteri* Cuvier, 1829 | *Upeneus tragula* Richardson, 1846 |
| *Sphyraena jello* Cuvier, 1829 | *Trichiurus lepturus* Linnaeus, 1758 |

Fig. 1. Filefish *Acreichthys tomentosus* (Linnaeus, 1758)

Leatherjacket' and fool fish. It belong to the family Monocanthidae comes under the order Tetraodontiformes. Filefish are generally found in shallow coral reefs and seagrass beds up to a depth of 15 m. The sea bottom in inshore waters of Kilakkarai coast was full of dead coral rubble covered with green and red algae. Seagrass were found in sandy area between the reef structures. The file fish (Fig. 1) was in orange colour, drifted according to the wave direction. It was looking very sluggish in nature. The body was very thin, laterally compressed and small spines were seen over the body. The pectoral fins were very small and difficult to see in underwater. The caudal fin was round with fan shaped rays. When tried to catch, it moved inside the dead coral crevices and could not find it further. Filefish are generally benthic solitary species, known as masters of camouflage. It changes its colour according to their habitats. It mainly feeds on tunicates, amphipods and polychaetes associated with seagrass blades.

# End-to-end modelling of marine fishery resources- optimal frontiers in data, calibration and coupling

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Chlorophyll based prediction of marine resource abundance has been in vogue in Indian context for quite sometime now. Potential Fishing Zones have been the glaring examples for the same. While such models take factors which are remotely sensed, thereby impacting mostly the pelagic resources, the modelling of other assemblages, especially the demersal resources, have been less focused upon. It is in this context end-to-end models such as individual based models (IBM) have more relevance. Of course, the success of such models depends a lot on the input data and the calibration for the region where they get deployed for study.

A set of marine fishery resource simulations were carried out for the south west coast of India with select candidate resources covering the vertical strata of niche column. Based on *in situ* sampling done with experimental forays at three depth zones on monthly basis, the critical input factors viz. the primary producers, prevalent in the region of study were identified and quantified and the abundance of lower trophic level (LTL) and higher trophic level (HTL) animals were arrived upon based on them, thereby completing the food chain. The simulated biomass was arrived at following the individual aggregating to cohorts then to schools and stocks thereby covering the entire niche biome. The interdependence amongst these resources too was enshrined using sub models. The modelling was complete with reproduction and recruitment and mortality phenomena incorporated along with the survival limitations flagged at appropriate stages.

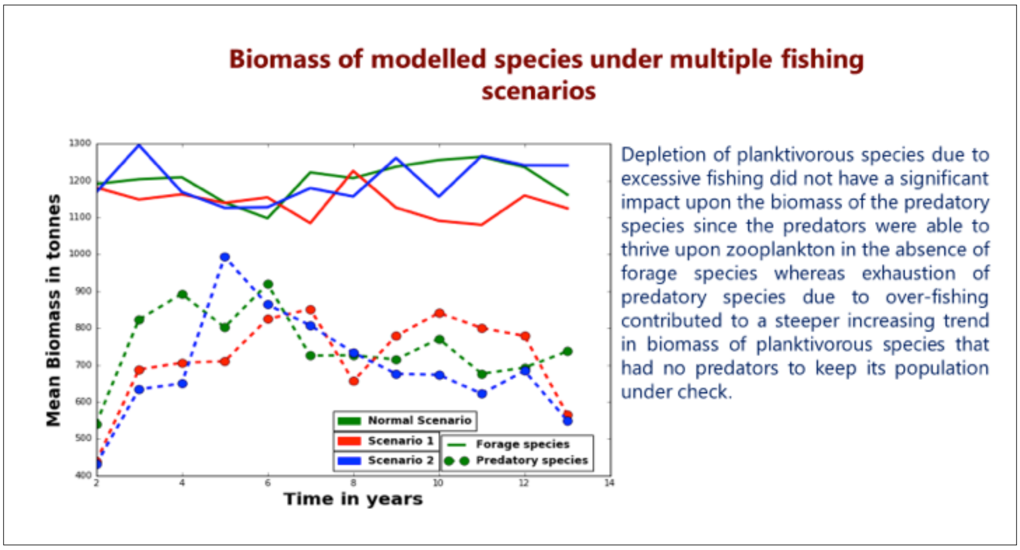


Figure1: Snapshots of the simulation trials

The simulation model was seeded spatially for various inputs and hence the trends and travails of each spatial sub-unit also got reflected in the reconstruction of the biomass. The model was calibrated for vital factors out of the twenty odd parameters and the larval food availability and mortality at larval stage came out as quite dominant.

This study, conducted using data primarily fed from Kerala and South Karnataka, gave a sufficient reflection of the limitations in data availability, especially the ones which can't be plugged in by other open source databases. The possibilities of coupling such models with biogeochemical models and models that project LTL were also attempted. The criticality of dynamic status of phenological crests and troughs undergone by the candidate resources and their preys and predators have a great say in the success of the simulation. An effort has been made to list out the best possible scenario (*Normal Scenario*: changes in biomass when both planktivorous species and their predators co-exist; *Scenario 1*: changes in biomass of the predators with the depletion of planktivorous species due to excessive fishing; *Scenario 2*: changes in biomass of the planktivorous with no predation) vis-à-vis Indian EEZ, with the type of data being collected by various mandated agencies including research organizations and presented in figure 1. An attempt has also been made to juxtapose the IBM approach with more complex approaches like stock synthesis.

# Fishery of *Sepioteuthis lessoniana* off Thoothukudi coast, Tamil Nadu

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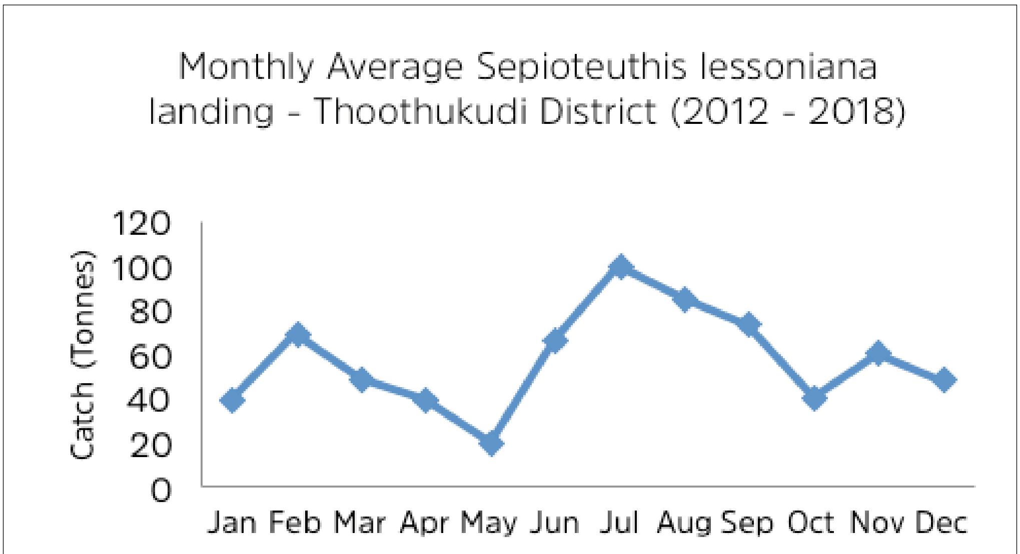
Cephalopods have emerged as valuable seafood resources in recent times because of the demand in export trade due to its high nutritive profile. During 2017, Indian cephalopod production was 0.220 million tonnes in which about 90% of the catch was exploited by trawl net. Gujarat (24.6%) contributed maximum to the total cephalopods catch followed by Tamil Nadu (23.6 %). Among the districts of Tamil Nadu Thoothukudi is one of the major cephalopod landing centres with an average annual catch of 3,462 tonnes during 2012-18. In Thoothukudi District, cephalopod resources are principally exploited by single day trawlers followed by hook and line (squid jigs). In recent years, the exploitation of cephalopod by gill net increased from 0.4 % (2012) to 15 % (2018). During 2012-18, nearly 56 % of cephalopods were landed by mechanised trawl; 31 % by outboard crafts operating hook and line, 8 % by gillnet and remaining 5 % by other gears.

Among the cephalopod species, *Sepioteuthis lessoniana* is one of the commercially important species with high export demand. From 2012-18, the *S. lessoniana* landing showed a fluctuating trend with peak production during 2018. The average annual landing of cephalopod was 676 tonnes during this period. In 2012, the catch was 669 tonnes which dwindled to nearly half (368 tonnes) in 2013. During 2014 to 2016, the catch was 597,642 and 511 tonnes respectively. In 2017 onwards there was a gradual increase in the fishery (747 tonnes)and in 2018 it reached to 968 tonnes. During the observation period the highest catch was recorded in July (100 tonnes) and the lowest catch was recorded in the month of May (20 tonnes). During the study period, the average CPUE of cephalopod for trawl net, hook and line and gill net was 1 kg/h,3.7 kg/unit and 0.2 kg/unit respectively. This species contributes nearly 17 % (321 tonnes), 25 % (265 tonnes) and 23% (58 tonnes) to the total cephalopod catch of trawl, hook and line and



gill net respectively. Other than *S. lessoniana* the major cephalopod species landed by trawl are *Uroteuthis (Photololigo) singhalensis* (24%) *Sepia pharaonis* (19%), *Sepia ramani* (12%), *Uroteuthis (Photololigo) duvaucelii* (12%), *Sepia prabahari* (11%)and Other species like *Amphioctopus marginatus, Amphioctopus neglectus* and *Octopus cyanea* are also represented in the landings in low magnitude. In hook and line, *S. pharaonis* (34%), *S. ramani* (25 %) and *O. cyanea* (16 %). In gill net, *S. pharaonis* was the dominant species. The Dorsal mantle length of *S. lessoniana* in trawl ranged from 5 - 40 (17.7cm) and in hook and line it was 11-39 (22 cm ). Price range of this species varies from ₹300 to 400/ kg based on the landing quantity and season.

# Diet of the Indo-Pacific blue marlin, *Makaira mazara* (Jordan & Snyder, 1901) caught off eastern Arabian Sea

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Diet of the Indo-pacific Blue marlin, *Makaira mazara* were studied based on 465 stomachs of both male and female fishes with fork length, 112cm- 274cm landed at Thengaipattinam harbour caught off Eastern Arabian sea during March 2017 to February 2019. Information on the feeding habits of billfishes from Indian waters is limited to *Xiphias gladius* and *Istiophorus platypterus*. Fishes were landed by multiday trawler cum longliner, which operates for about 8 to 20 days at sea to obtain the catch. A total of 32 prey species identified from the stomach during different seasons. The diet consists of Carnivore fishes (46%), Omnivore fishes (32%), Small planktivores (9%), Cephalopods (8%) and Crustaceans (5%). The major food item observed was Tunnies followed by Mackerels, Scads, Squids, Cuttle fishes and Crabs. The contribution of finfishes to the marlin diet was higher in terms of %W, %F and %IRI. The fullness index was determined and depicted the highest percentage for ¼ full stomach followed by ½ Full, Empty, Full and ¾ Full. More than 40% of the fishes landed were juveniles and sub-adults with full or ½ full stomach. The diet consists of small-sized fishes irrespective of the predator body length. More than 90% of the prey's length was less than 5% of the total length of the predator. The percentage of empty stomach increases with body size, where the large-sized fishes with high Gonadosomatic index are always with ¼ full and empty stomachs. The GSI was high from September to December and showing a small peak during February -May. The high diet breadth index calculated for the fishes shows the flexibility in the food preference, where the fishes can shift to different categories of food in response to the flux in their abundance. The present study forms the basic information on the diet of *M. mazara* caught of the eastern Arabian sea, will be an essential fact to understand the prey-predator relationships and trophic dynamics of the waters. It also helps the fishers to come up with bait management strategies to select appropriate baits for longlining.

# The fishery and biology of *Meretrix casta* (Chemnitz) in the Chunnambar estuary, Puducherry

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*Meretrix casta* forms an important fishery in Chunnambar Estuary and contributes about 83% to the bivalve fishery of the water body. The fishery, fishing method, species contribution, size range and biology of bivalves are presented in this study. Clam fishing was carried out throughout the year and they are exploited by traditional method of hand picking from shallow areas during low tide mostly by women and children. Another method of fishing is done by men using a scoop or bag net attached to a pole operated from a canoe. Nearly 25 to 30 fishers are engaged in clam picking activity on a regular basis. Each fisher spends about 5 to 6 h per day for fishing and collects about 20 to 30 kg per day. The *M. casta* forms the dominant bivalve fishery followed by *Marcia opima*. The average annual landing for the period 2016-18 was 279 t. The fishery is uniform throughout the year except unfavourable conditions like natural calamities. Clams of length range 14 to 49 mm size forms the fishery. The species is found to be a continuous breeder while the peak spawning season is from August to December. Bivalve meat is used for domestic purpose. The peak spat settlement period is in January and February. The fishing is continuous and a significant harvested clams are below 30mm mantle length. This continuous exploitation of small individuals may lead to growth overfishing. Therefore, the exploitation of small sized clams (<30mm) must be prevented or reduced to a sustainable level particularly during peak spat settlement period to increase the productivity of the clam resources.

# Adaptive management measures adopted for *Paphia malabarica* fishery in Ashtamudi Lake

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Ashtamudi Lake supports the livelihoods of around 3000 fishers involved in processing and trading clams as a meat or whole clam. But in the recent years, catches are declined to below 12, 000 tonnes which was the target reference point (TRP) fixed for Ashtamudi short neck clam *Paphia malabarica* even in last year (2018) catch was below the 6000 tonnes which was the limit reference point (LRP) fixed for *P. malabarica*. Annual biomass studies of the recent years also did not show any encouraging results. So it is a high time to use adaptive management measures for this clam fishery. Like other fisheries, clam fisheries are highly dynamic practices involving dynamic fishing behaviours, changing environmental conditions, variable productivity of the resource and fluctuating market and economic conditions. Therefore, managing the resource adaptively is very important. Adaptive management measures must be designed to be flexible and adaptive to changing conditions i.e. to evaluate and adjust decisions periodically based on observations about fishery conditions and learning from the outcomes of previous management decisions. Based on the target species, identified the suitable performance indicators which are the model outputs that impart information about the current status of the population i.e. they reveal how things are going. For example (Table 1 & Fig.1)

Table 1. Species performance indicators and adaptive measures of Ashtamudi short neck clam fishery

| Performance indicator | Data needed | Example of TRP | Example of LRP | Example of actions taken through clam council |
|---|---|---|---|---|
| Total catch | Catch data | Total catch increasing | Total catch decreasing drastically | If catch < LRP:<br>1) reduce fishing days<br>2) Increase surveillance and inspection on mesh & clam size. |
| Catch rate | Catch & effort data | CPUE increasing | CPUE decreasing rapidly | 1) limiting effort and its impact on catch rates<br>2) strictly implement no-take sanctuary zone<br>3) strictly enforce the Minimum legal size (MLS) |

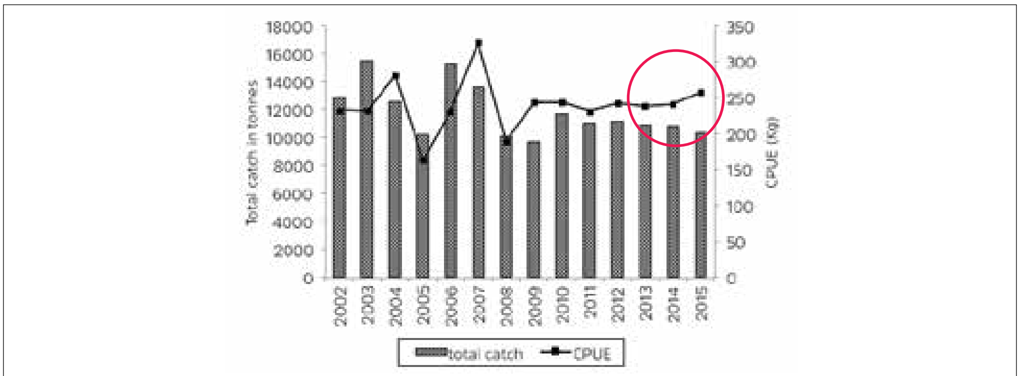


Fig. 1. Catch and catch rate of *P. malabarica* in Ashtamudi Lake during 2002-2015

# Assessment of dimorphic growth of the cuttlefish *Sepia pharaonis* (Cephalopoda: Sepiidae) using cuttlebone markings from the south-eastern Arabian Sea

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The pharaoh cuttlefish *Sepia pharaonis* Ehrenberg, 1831, is one of the most important species exploited along the Eastern Arabian Sea. A study on the relationships between dorsal mantle length (DML) and number of cuttlebone septa (or chambers) and between total body weight and number of cuttlebone septa were carried out in *S. pharaonis* collected from the south-eastern Arabian Sea. The cuttlefish samples were collected from Cochin Fisheries Harbour (133 males and 67 females). Dorsal mantle length-at-chamber count and weight-at-chamber count were statistically higher in males than in females. The available literature suggests that females of *S. pharaonis* are heavier than males while males are found to attain greater ultimate lengths throughout the lifecycle. Literature also suggests that the rate of cuttlebone septum formation is the same in both sexes of *Sepia* species, however in the present study, *S. pharaonis* males have slightly higher growth rates than females (Fig. 1 & 2). The study indicates that there is considerable scope to use cuttlebone chamber counts as a means of determining actual age of cuttlefishes.

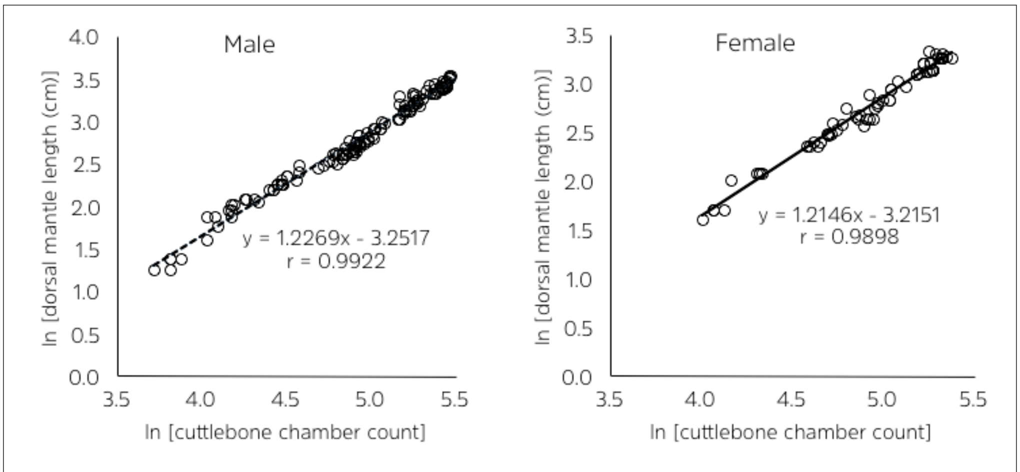


Fig. 1. Relationship between dorsal mantle length (DML) and cuttlebone chamber count (CN) for males and females of *Sepia pharaonis*. Log-transformed data with regression lines.

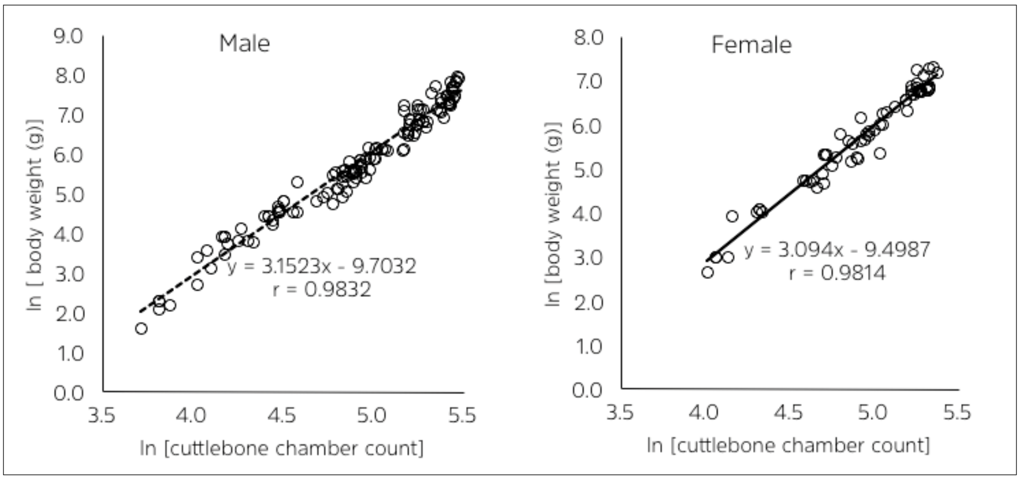


Fig. 2. Relationship between body weight and cuttlebone chamber count (CN) for males and females of *Sepia pharaonis*. Log-transformed data with regression lines.

# Fishery and population dynamics of lizardfishes exploited by trawlers from coastal waters along the Coromandel coast of India

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Lizardfishes constitute about 2% of the annual trawl landings at Chennai. The dominant species that occur regularly are *Saurida undosquamis*, *S. tumbil* and *Trachinocephalus myops*. Other species which also often occur include *S. longimanus* and *S. micropectoralis*. The fishery of lizardfishes by trawlers from coastal waters along the Coromandel Coast of India was studied based on trawl landings at the Madras Fisheries Harbour (MFH) in Chennai during the period 2012-2017.

The annual landing of lizardfishes in these years was 596, 520, 558.2, 748.7, 650.1 and 372 t respectively, with catch rates of 1.0,1.1,1.3,1.5,0.8,0.5 and 1.5 kg/hr. Lizardfishes formed 1.8, 1.9, 1.9, 2.4, 1.9, 1.5 and 2.4% respectively of the total trawl landings at MFH during these years. *Saurida undosquamis*, *S. tumbil*, *S. micropectoralis*, *S. longimanus* and *Trachinocephalus myops* were the species that contributed to the landings.

Growth and exploitation of two species - *S. tumbil* and *S. undosquamis*, were estimated using length frequency data compiled from weekly samples of the species landed by trawlers at MFH during the study period. von Bertalanffy growth parameters were estimated through ELEFAN module of FiSAT, Natural mortality using Pauly's empirical equation (Pauly, 1980), total instantaneous mortality using length converted catch curve method (Pauly, 1983), fishing mortality from the difference between the previous two and

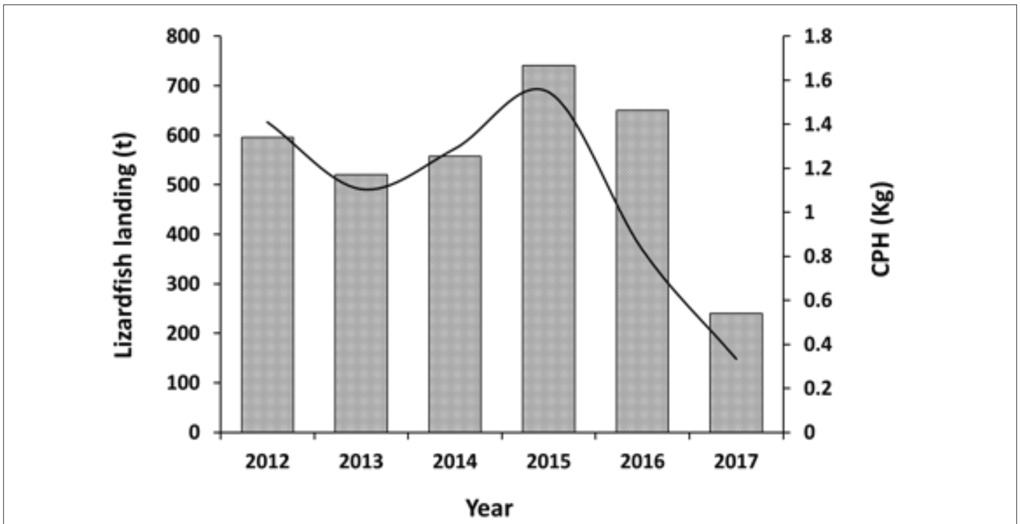


Fig. 1. Landing and catch rate of lizardfishes by trawlers at Chennai (2012-2017)

exploitation rate from the derived values of F and Z.

The von Bertalanffy growth parameters $L_{\infty}$, K and t0 were estimated as 574.5 mm, 0.58$y^{-1}$ and -0.019y for *S. tumbil* and 396 mm, 0.61$y^{-1}$ and -0.0221y for *S. undosquamis*. Longevity of these species was estimated as 5.2 and 5 years, respectively. The natural mortality co-efficient 'M', annual fishing mortality 'F' and instantaneous mortality rate 'Z' were estimated to be 0.55, 0.91-1.06 and 1.45-1.61 for *S. tumbil* and 0.92, 0.88-0.91 and 1.83-2.04 for *S. undosquamis*. The annual exploitation ratio 'E' and exploitation rate 'U' were found to range between 0.62 and 0.66 and 0.47 and 0.53 respectively, for *S. tumbil* and 0.52 to 0.56 and 0.42 to 0.49 for *S. undosquamis*, indicating that the species are currently being exploited to near optimum levels.

# Bringing spatial sense to the geographic distribution of marine fishes in the Indian waters

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Fisheries form an integral part of coastal communities and promote economic growth and nutritional security of India. It also contributes to the well-being and livelihood of many other countries. Sustainable and productive fisheries protect the environment and natural resources. The knowledge of the spatial distribution of fish species in the specified area needs to be examined for the effective utilization of fishery resources and for planning conservation policies and management activities. This study focuses mainly on the spatial analysis of geographic distribution of marine fish species in the Indian waters. The data on the geographic distribution of the species in this period was collected by literature survey and open databases. The information is compiled to form a database and it is subjected to spatial analysis using ArcGIS software. The study helps in understanding the current geographic distribution of marine fish species in the Indian waters. The spatial and temporal distribution of the marine species helps in understanding the factors influencing the pattern of dispersal of the fish community. It can also be used to compare the changes or shift in distribution species in the future. The abundance of species can be considered as an indicator of ecosystem health. So, it can be used to dictate the pollution and environmental quality. This study lays a strong foundation for the formulation of conservation and management advisories of marine ecosystem in future.

# Age and growth of the Indian squid *Uroteuthis duvaucelii* based on statolith microstructure analysis from the tropical Arabian Sea

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The Indian squid *Uroteuthis duvaucelii* is distributed widely in the continental shelf waters of the Indo-West Pacific Seas and also contributes a major share of the annual squid landing from the Indian waters. Age and growth rate information is one of the most important set of variables for estimating population dynamics of the species. Earlier works on the age and growth of squids along the Indian subcontinent were mainly based on length-frequency analysis. Recent studies have proven that length-frequency analysis overestimate the life span and underestimate the growth rate of squids. Therefore, the aim of this study is to understand the age and growth of the Indian squid in the Arabian Sea based on analysis of the statolith growth increment, which has already been applied to growth studies in many squid species. A total of 432 (male: 235; female: 197) individuals of the Indian squid were sampled from the commercial trawlers operating along the southwest coast of India.

The dorsal mantle length (DML) of the aged individuals ranged from 30 to 350 mm (30-350 for males and 32-207 mm for females). Based on statolith increment counts, the youngest squid was a 53 days old male with a DML of 33 mm. The maximum age was observed 146 days in females (160 mm DML) and 170 days in males (296 mm DML). The Indian squid, is therefore a fast-growing squid. The absolute daily growth rate of the females ranged from 0.43 mm to 1.91 mm DML/day and in males it ranged from 0.44 to 2.41 mm DML/day. In either sex, the highest value of instantaneous growth rate of males (13.65 %) and females (13.62 %) was observed in 75 days old individuals. After the age of 75 days the instantaneous growth rate got decreased gradually to 1.9% for females and 0.3% for males.

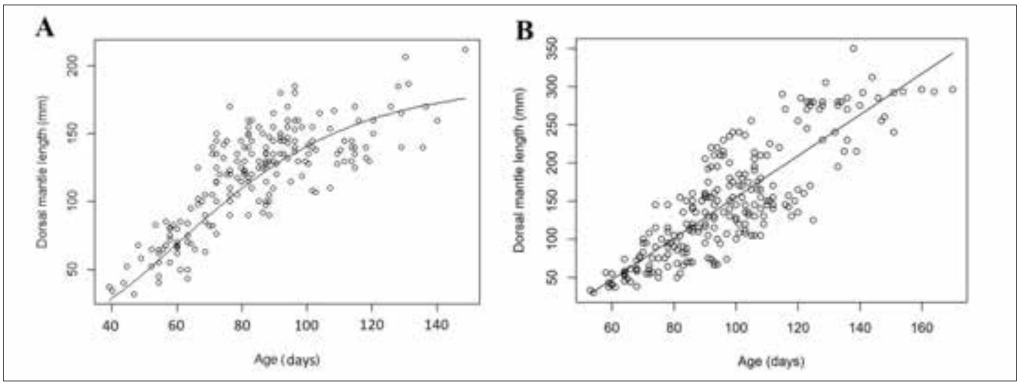


Fig.1 Relationship between dorsal mantle length (DML) and age of females (A=Gompertz) and males (B=Linear) of *Uroteuthis duvaucelii* from the Arabian Sea

Total six growth models for size at age data such as Linear, Von Bertalanffy, Power, Schnute, Exponential and Gompertz were fitted for both male and females. Using the Akaike's Information Criterion (AIC), the growth pattern of *U. duvaucelii* from the Arabian Sea was best described by the Gompertz model for females ($L_\infty$= 195 mm (SE: 13.02) and Linear model for males (Fig.1 & Table. 1).

Table.1 Growth model selection for males and females of *Uroteuthis duvaucelii* from the Arabian Sea; AIC= Akaike's information criteria; Δ*k*= Differences in AIC; *Wk*= Akaike weight. Bold font indicates the selected models

| Model | Males | | | Females | | |
|---|---|---|---|---|---|---|
| | AIC | $\Delta^k$ | $W^k$ | AIC | $\Delta^k$ | $W^k$ |
| Linear | 2482.05 | 0.000 | 4.033307e-01 | 1915.94 | 61.534 | 4.149685e-14 |
| Von Bertalanffy | 2482.90 | 0.848 | 2.639492e-01 | 1860.52 | 6.105 | 4.510966e-02 |
| Power | 2493.23 | 11.177 | 1.508713e-03 | 1910.12 | 55.704 | 7.655677e-13 |
| Schnute | 2998.02 | 515.961 | 3.682593e-113 | 2347.52 | 493.108 | 7.996718e-108 |
| Gompertz | 2482.45 | 0.394 | 3.312114e-01 | 1854.41 | 0.000 | 9.548903e-01 |
| Exponential | 2524.07 | 41.961 | 3.118501e-10 | 1939.52 | 85.108 | 3.154904e-19 |

# Length-weight relationship of four glassy perchlets from a tropical lake along the south west coast of India

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Fishes of the family Ambassidae commonly known as glassy perchlets are represented by three genera in Indian subcontinent: *Ambassis, Chanda* and *Parambassis.* Glassy perchlets are small to medium-sized semitransparent fishes commonly used for aquarium purposes. The present study provides the length-weight relationships (LWRs) of four glassy perchlet species collected from Vembanad tropical lake, South west coast of India. The species studied were *Paramassis dayi* (Bleeker, 1874), *P. thomassi* (Day, 1870), *Ambassis ambassis* (Lacepe'de, 1802) and *A. gymnocephalus* (Lacepe'de, 1802). The fish specimens were collected from the catches of gill nets and seine nets operated in the lake during the period 2014-2015. The *b* values in the LWRs were varied from 2.75 to 3.27. No previous information is available on LWRs for these fish species from Vembanad lake. The findings of the present study will be useful for conservation and sustainable management of the glass fishes.

# The status of cockle fishery at Kakinada Bay, India

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In India, the molluscs contribute to important fisheries, providing nutritious food and are also foreign exchange earners to the country. Phylum Mollusca constitutes dominant sea food resources such as clams, oysters, cockles, gastropods and cephalopods. Among molluscs, especially the bivalves support the fishery sector of our coastal communities. Men, women and children participate in fishing bivalves, which provide employment and income in coastal areas.

Kakinada Bay is an important bivalve fishing area along the East coast of India. The major crafts used for the fishery are 'Nava' and fibre 'teppas'. They usually engage in handpicking with the help of plastic baskets for storing the collected clams. The estimated standing stock and potential yield of clams and cockle fishery of Andhra Pradesh is about 58,000 and 49,300 tonnes respectively by the short term survey of estuaries. The species of cockles (blood clams) *Anadara (Tegillarca) granosa* and *A. (T.) rhombea* coming under the class Bivalvia, family Arcidae and Subfamily Anadarinae have fishery importance. In Kakinada Bay, the blood clam bed has a spread of 46.6 $Km^2$ areas and the species is collected throughout the year by fishermen residing in 15 villages. The blood clam production from Kakinada Bay was about 250 t in 2012, peaked to about 417 t in 2016 and then declined drastically to 213 t in 2018. Blood clams contribute about 46% to total clam production and 36% to total bivalve production. The average catch per unit effort per year is about 3.5 t.

In Andhra Pradesh, more than about 60% are exported for meat purpose, 30% are used as a major ingredient of shrimp feed and the remaining for shell industry. Very negligible part is used for domestic consumption. The extensive shrimp farms also use dried and boiled clam meat as shrimp feed. Apart from these, the shells are used in the manufacture of cement, calcium carbide, sand-lime bricks and lime. The lime shell is used as manure in coffee plantations, as mortar in building construction, in the treatment of effluents, as a pesticide by mixing with copper sulphate and in glass, rayon, polyfibre, paper and sugar industries. Bivalve shells with attractive sculpture like blood clams are used by the ornamental shell craft industry. Bivalve populations as a source of food, ornamental purposes and commercial uses have brought them under the shade of endangered species. The mean size of *Anadara* sp. in the fishery too shows a decreasing trend from 44 to 40 mm. Here comes the necessity of management of the stock. So we have to go for the minimum legal size for the exploitation (30 mm) and the closed season (Dec-Jan) for sustaining the resources.

# Phenological shifts in Oil sardine *Sardinella longiceps* (Valenciennes, 1847) due to climate change along southwest coast of India

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Climate change has become a heated discussion globally, with emphasize on global warming. Most of the warming experienced during the last 50 years is attributable to human activities. An overall higher temperature on Earth, sea level rise, alteration in local climatic conditions, shift in the proliferation of living beings are the most obvious examples of the consequences of climate change. However, researchers have demonstrated higher rates of shifts in aquatic species distributions and phenology as compared to terrestrial systems. Marine fish reproductive cycle is a harmonious process interlinked with environmentally mediated routine of aquatic ecosystems. Therefore, the understanding of changes in phenology of marine fish stocks in relation to climate change is critical for sustainable exploitation and ecosystem based fisheries management. Shifting in scheduling of reproduction has dramatic effects upon the recruitment success of fish population throughout the food web. The different life stages of the species show varying susceptibilities to temperature rise in different seasons. In India, oil sardine is recognized for highest contribution in the total marine fish catch. The fluctuations of oil sardine fisheries have significant impact on overall Indian marine fish production. Diverse factors are responsible for the success of its fishery such as ideal reproduction cycle, larval survival and recruitment to the fisheries, suitable hydrological conditions, availability of necessary food items for the fry and juvenile and periodical migration into offshore waters. In this study, the anomalies of sea surface temperature (SST) and rainfall along southwest coast of India were analyzed to observe the shift in the trend of SST and rainfall time series data collected from various open access sources. Also, Southern Oscillation Index was examined, which has significant role in the

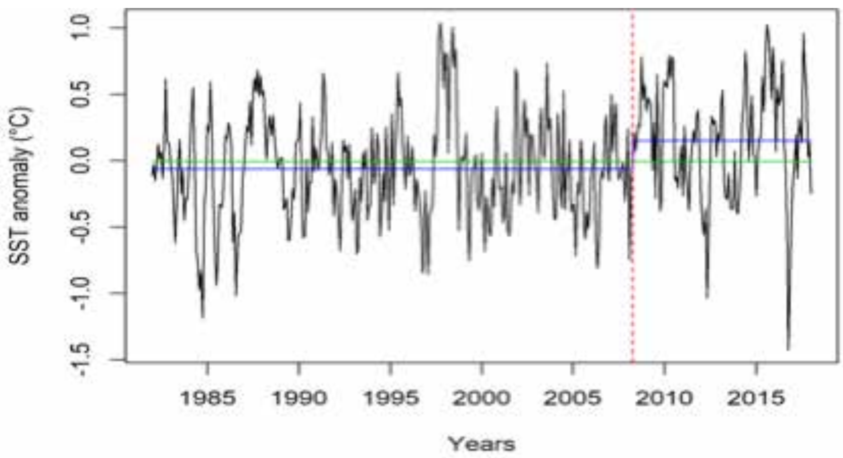


Fig. 1. Trend of sea surface temperature anomaly

completion of successful reproduction in oil sardine. Further, the study on all available publications related to oil sardine were synthesized to observe the consistency of phenology under climate change. Over the years, its length at first maturity decreased from a reported 16.75 cm in 1964 to 15 -15.2 cm after 2000. Similarly, the alterations in peak spawning season and life span were noticed. During 1924, oil sardine was able to peak its spawning from September and continued for a short period up to October. But, recently, it has been reported that oil sardine can complete its peak spawning season a quarter year earlier as compared to historical period.

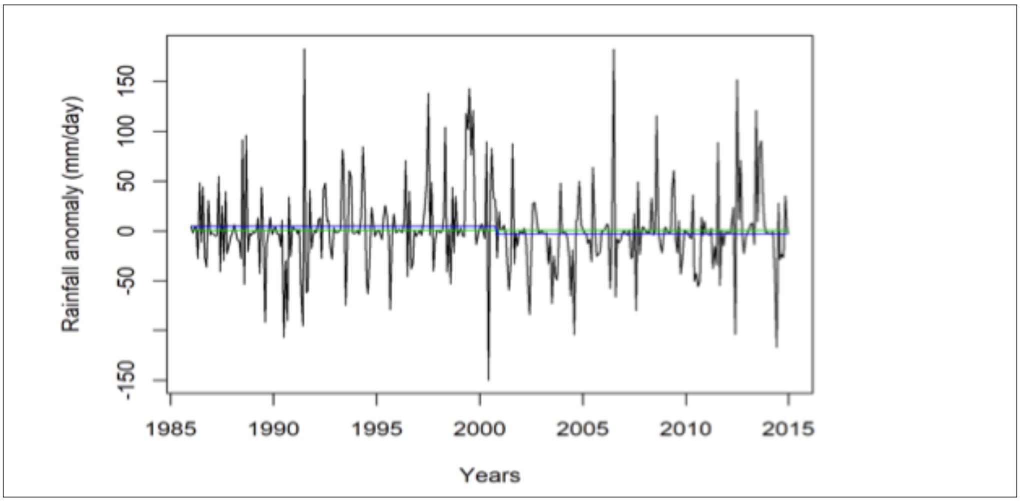


Fig. 2. Trend of rainfall anomaly

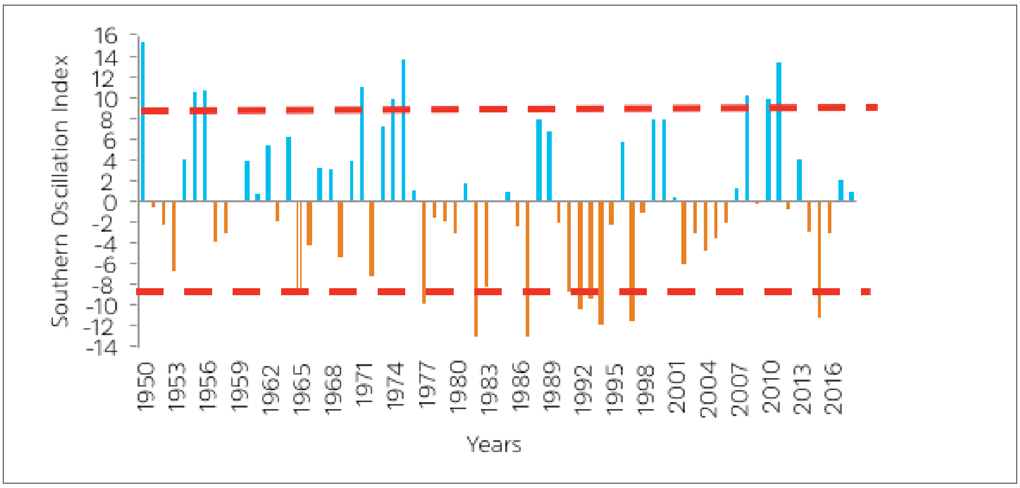


Fig. 3. Trend of southern oscillation index

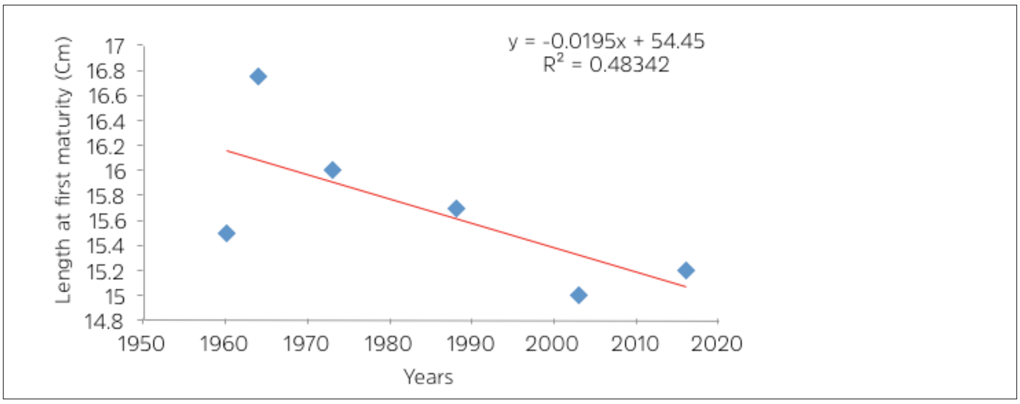


Fig. 4. Declining trend for length at first maturity of oil sardine

# Deep Sea communication methods to enable safe and sustainable fishing in North Indian Ocean

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Importance of Indian Marine Fisheries is well established. Due to severe oceanic weather and cyclones its sustainability in terms of livelihood and life security is now increasingly challenged. Year 2019 saw formation of record breaking very severe cyclonic and super cyclonic storms in North Indian Ocean. Fishers who venture out in deep sea for fishing before the onset of the cyclone remain unaware of impending storms leading to grave consequences.

This necessitates the accurate and timely oceanic information such as wind speed and direction, wave height, surge, cyclones and their positions, tsunami, etc. and is very crucial for the sustainable fisheries. ESSO-Indian National Centre for Ocean Information Services (INCOIS), ICAR Central Marine Fisheries Research Institute (CMFRI) Mumbai and TCS Research and Innovation Lab Mumbai collaborated to create a multi-language simple to use mobile application to provide the information like Potential Fishing Zone (PFZ) maps, Wind Speed and Direction maps, Wave height information, Swell, cyclonic and Tsunami warning. Though this information is updated periodically, due to weak signal of the mobile data network beyond 8-10 km from the coast users reported practical issues. CMFRI and TCS conducted a scientific study during 2013 to 2015 under World Bank-GEF supported project to evaluate various communication methods available for deep sea (20 km and beyond from the nearest coast) communication.

Earlier study critically reviewed the use of the Very High Frequency (VHF) based transceivers (also called Walkie-talkie), Satellite phones, Direct To Home (DTH) broadcast and mobile communication. Each type of the communication method has some associated benefits as well as challenges.

Satellite based communication included, satellite phones and Satellite based Direct To Home (DTH) Services. Use of Satellite phone have own challenges. Earlier Mobile cellular communication was attempted to establish that mobile signals can go up to 32 km in sea.

From end user convenience, mobile signal extension looked better but major drawback of this setup was the financial sustainability. When these experimentation and study seems to be useful GPS Aided GEO Augmented Navigation (GAGAN) is a step by the Indian Government towards initial Satellite-based Navigation Services in India. It is a system to improve the accuracy of a global navigation satellite system (GNSS) receiver by providing reference signals. It works on the concept of DTH.

GAGAN is consisting of GSAT-8, GSAT-10 and GSAT-15 and it covers the entire Indian Ocean round the clock. GAGAN chips are embedded in a portable transceiver device called GEMINI (GAGAN Enabled Mariner's Instrument for Navigation and Information). Alerts and other messages like PFZ, wind, wave etc. are sent through GAGAN and the GEMINI device receives and transfers it to a customized mobile phone app through blue tooth communication. The mobile application would decode and display the information. Currently the GEMINI device costs ₹8000. Only limitation of this is that the dedicated app must be used, unless the Bluetooth data transfer protocol and APIs are made open source to make it compatible with other applications like mKRISHI® Fisheries and FFMA. Moreover, the information as of now is one way, that is from satellite broadcast to the device.

Collaborative scientific pilot studies are crucial to solve such important challenge of the food security, livelihood and human and environmental safety. This can also help Coast Guard, Navy, Research Organizations like INCOIS, local district police and the marine fishers to remain connected with each other and increase the surveillance. Building "Digital Information Highway - in sea".

Technological developments after 2015 and changed scenario both in technologies and fishing practises require an assessment of the options predicted earlier and now taking shape to enhance sustainability of the system.

Table 1 North Indian Ocean Cyclones in 2019

| Tropical Cyclone Type | Name | Month | Location |
|---|---|---|---|
| Cyclonic Storm | Pabuk | Jan | Bay of Bengal |
| Extremely Severe Cyclonic Storm | Fani | Apr - May | Bay of Bengal |
| Very Severe Cyclonic Storm | Vayu | Jun | Arabian Sea |
| Deep Depression | BOB 03 | Aug | Bay of Bengal |
| Very Severe Cyclonic Storm | Hikaa | Sep | Arabian Sea |
| Land Depression | 01 | Sep | Arabian Sea |
| Super Cyclonic Storm | Kyarr | Oct | Arabian Sea |
| Extremely Severe Cyclonic Storm | Maha | Oct - Nov | Arabian Sea |
| Very Severe Cyclonic Storm | Bulbul | Nov | Bay of Bengal |

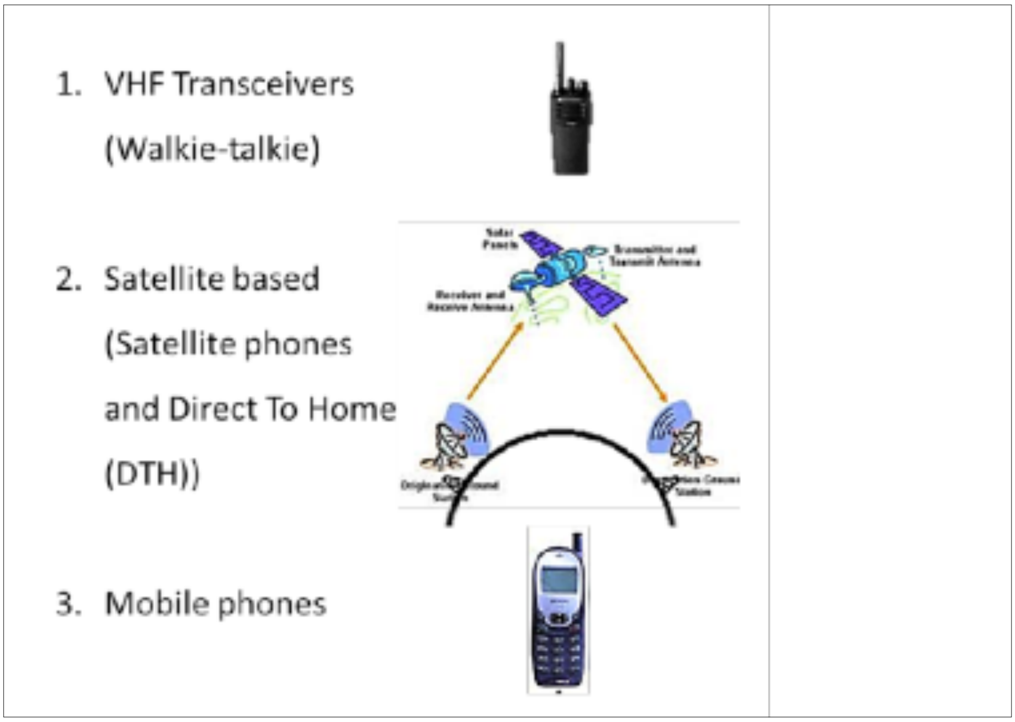


Figure 1 Communication methods studied for deep sea communication

# Association of marine finfish and shellfish with the marine environment off north Andhra Pradesh

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The spatio-temporal dynamics and association of marine finfish and shellfish distribution with environmental variables off Visakhapatnam was studied based on experimental trawling data. Trawling was conducted from 2014-2018 in areas of 20-50m depth off Visakhapatnam. Water quality parameters were also estimated from the fishing location. Species composition for each haul was studied. All the species caught in each haul was identified up to genus level and species-wise/genus-wise weight was recorded. Catch rates were estimated in terms of kg/h. Over 300 species were recorded during the study period; however for this study catches of only 65 species which had continuous data were used for the analysis. During the study total catch per trip ranged from 0.4 kg to 115.8 kg. The average catch rate was 22.1 kg/h (range 0.3 kg/h to 71.6 kg/h). Pelagic resources had the highest average catch rate (0.74 kg/h), followed by molluscan resources (0.31 kg/h), demersal (0.27 kg/h) and crustaceans (0.13 kg/h). Most resource groups showed seasonal variation in catch rates. Pelagic and molluscan resources had higher catch rates during the winter months (Oct-Mar) whereas demersal and crustacean resources had higher catch rates during the summer months (Apr-Sept). Crabs and gastropods showed higher catch rates in areas of 50 m depth. Stomatopods on the other hand had higher catch rates in areas quite close to the shore in areas of 20 m depth. Most of the demersal finfish resources were found in areas of 30 m depth. Among the environmental variables, nitrate, Chlorophyll and phosphate values had the highest influence on catch rates (proxy for abundance). Filter feeders like lesser sardines had higher catch rates in areas of higher nitrate and Chlorophyll values. Catch rates of demersal finfish were mainly influenced by Total Suspended Solids, nitrate, Chlorophyll and salinity. Catch rates of shellfish like crabs and stomatopods were mainly influenced by nitrate values. Cephalopods showed higher catch rates in areas of higher primary productivity.

# Fishery and growth parameters of *Metapenaeus affinis* (Milne-Edwards, 1837) off Andhra Pradesh, India

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The shrimps of the genus Metapenaeus are a commercially valuable component of western Bay of Bengal and form about a third of the trawl penaeid landings. We studied the fishery of *Metapenaeus affinis* from January 2017 to October 2019 Visakhapatnam. Assessment of population parameters of the species was done using length frequency data. Five species of the Metapenaeus genus contribute to the fishery, namely *M. monoceros, M. dobsoni, M. affinis, M. brevicornis* and *M. ensis.* Fishery of the genus Metapenaeus contributed to about 31% of the total penaeid trawl catch during the study period. While *M. affinis* contributed to 20.3% of the Metapenaeus trawl fishery, 6.3% is its contribution to the annual penaeid trawl catch (average) during 2017-2019.

The annual catch for *M. affinis* of Andhra Pradesh waters for the period of 2017 and 2018 (average) was 552.9 t. The length range of the species in the fishery was 78 mm to 193 mm for females and 78 mm to 168 mm for males with the modes at 138 mm for females and 133 mm for males. The average mean length for the study period of female and male was 138.8 mm and 126.5 mm respectively. The male to female sex ratio was 1:1.12. The total length of the females at first maturity was found to be 117.3 mm. Spent-recovering individuals were seen in June to August and December and February. The Von Bertalanffy parameters obtained for both the sexes were, females ($L_\infty$): 206 mm; K: 1.8 $yr^{-1}$ and males ($L_\infty$): 176 mm; K: 2.1 $y^{-1}$.

The present study is an attempt to generate information on biology and growth parameters of the species form the east coast of India. To date no work has be done on the species form this coast and the study gives baseline scenario of this exploited fishery which will help in formulating management guidelines for sustainable harvest of the resource from east coast.

# Assessment of settlement of spat of black clam, *Villorita cyprinoides* in Vembanad Lake based on surveys

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Among bivalves the black clam, *Villorita cyprinoides* is the most important species landed in India. The state of Kerala has been, by far, the leading producer of the species. Major proportion of the species is harvested from Vembanad Lake, followed by the Malabar Coast. Surveys were conducted in several areas of Vembanad Lake to study the spat fall, recruitment time etc. of the species. Surveys were conducted in Vaikom and Panavally area of the Vembanad Lake. In Panavally area on the northern side of the Thannermukkam barrage of the Vembanad lake, surveys were conducted twice in 2018 in April and November in a stretch of 2000m length and 1000 m width covering the lat-long 09$^0$ 49' 389'' N to 09$^0$ 49' 832'' N and 76$^0$ 21' 530'' E to 76$^0$ 22' 565'' E. Heavy settlement of black clam spat was observed in an area of 1500m length and 500m width in the month of April. The observed spats were approximately 3 months old. Measurements of Length and weight were taken for a minimum of 30 samples from each sampling Total spat biomass of *V. cyprinoides* in the survey area was estimated both in terms of numbers and weight. Total spat biomass was estimated as 109440000 numbers/ha and 1969.92 kg/ha in weight. It is estimated that it will produce 1642 MT/ha, if the spat is not indiscriminately exploited. The same area was surveyed again in November 2018 to study the growth rate of the spat of black clam. Growth rate of the spat was calculated as 0.017 mm/day. In Vaikom area of Vembanad Lake, surveys were conducted in a stretch of 200 m length and 50 m width covering the lat-long 9$^0$ 43' 559'' N, 76$^0$ 22' 980'' E to 9$^0$ 44' 628'' N, 76$^0$ 23' 402'' E. Total spat biomass was estimated as 26920000 numbers/ha and 7066.5 kg/ha in weight. Physical and chemical characteristics of water and sediment were analysed for both areas. The values of oxygen concentration, chlorophyll concentration, Total suspended solids of water and sand percentage (>75%) in the sediment were in the ideal range in both areas.

# Marine fish catch survey and analysis software: a transition to online data collection and processing for marine fisheries management in India

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Marine fishery plays a vital role in India by providing food security, employment and income generation. For sustainable management of marine fishery resources, stock assessment using information on fished taxa is an essential requirement. In a multi-species, multi-gear fishery prevailing in the country, the mechanics behind fish data collection and management is remarkably complex. ICAR-Central Marine Fisheries Research Institute is responsible for monitoring and assessment of marine fisheries in the country. The institute has developed a unique method for estimation of fishery catch and effort all along the coastline. The sample survey design is based on a Stratified Multistage Random Sampling Method with space-time stratification, which was evolved after years of field-trials to suit the very special conditions prevailing in the country. With a coastline of 8,129 km, 0.53 million km$^2$ of continental shelf and 2.02 million km$^2$ of Exclusive Economic Zone (EEZ), the sampling area covers 1265 fish landing centres situated along the 9 maritime states and 2 union territories in the mainland of the country.

The data on fish landings and effort expended was collected from different landing centres according to the sampling plan and paper-based reporting by the staff. On receipt of this, data is manually entered and processing was done at headquarters to arrive at resources-wise landings estimates every month with time lag of minimum three months. In the year 2018, CMFRI made a transition in the data collection and estimation system by developing a web-

based application software named *Marine Fish Catch Survey and Analysis (FCSA*) and other necessary hardware implementation.

This application consists of different segments, *viz*., online data entry using tablets, utilities for scrutiny of data, analysis, estimation and various report generation. It allows a multi-level user system ranging from those who collect the real time data from the landing centres to the system administrator who controls the whole system. Other types of users include (1) Head of Fishery Resources Assessment Division/Scientists of the division, who supervise and guide the whole process of implementation of sampling plan (2) Data analysts at the headquarters who prepare the work schedules for data collection, estimate/analyse after verifying the submitted data (3) Scientist-in-charges of different research centres who can view the work schedules as well as the submitted data of their respective centres (4) Other users who can access the data and various types of reports. Each user is provided with user name and password to login and access the system accordingly.

FCSA has been developed to streamline, organize and evaluate the field data collection utilizing small, portable electronic tablets as well as data analysis and reporting. This provides a new way to manage the field and computing work with a range of catch and effort information including fishing location, vessel and gear type and price. The application hosted in Oracle server also facilitates interlinking between catch, effort, biological and socioeconomic data. The data transmission can be performed even without network connectivity and the information is uploaded once connectivity is restored. This allows working in remote places or areas with limited internet access. GPS, time and date-verified work are used to monitor the data collection process and to map the location of landing centres and fishing harbours. Moreover, this can be combined with data in other formats such as maps, images, audio and video, to substantiate the information provided. In addition to improved efficiency, the tablet based data collection substantially reduce cost and time lag in reporting when compared with paper-based practices. This real-time application software supports assessment of resources and formulation of fishery management plans under the changing regulations in the current system of research and developmental activities in the fisheries sector.

# Catch composition of prawns in dolnet landings of Gujarat and estimation of sustainable yield for genus *Metapenaeus*

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Dolnets are specialized bag nets operated along the Gujarat coast. The fishery is unique as it uses the tidal current for catching and retention of fishery resources in it. In addition, the fishery has very narrow spatial expansion. Shrimps/ prawns forms one of the major component of dolnet catches. Out of the total shrimp/ prawns landings almost 84% comprised of *Acetes* spp., a high volume and low value fishery. Other shrimps/ prawns accounted for remaining 16%. Among other shrimps, *Nematopalaemon tenuipes* (44.1%) and *Exhippolysmata ensirostris* (16.2%) forms the bulk of the fishery. The contribution of members of genus *Metapenaeus* is limited to only 3.6% but it fetches good price in local market. Four species of genus *Metapenaeus* are recorded, with dominance of *Metapenaeus affinis* (69.6%) followed by *M. monoceros* (14.6%), *M. kutchensis* (9.5%) and *M. brevicornis*(6.3%). The study is aimed at estimating the maximum sustainable yield for the genus *Metapeaneus* from the dollnetters, as the Dolnet operation are restricted in spatial expansion with limited overlap of fishing ground with other gears. The Fox and Schaefer surplus production model were applied. The estimates of MSY were 1525 t (Fox model) and 1276.6 t (Schaefer model). Schaefer model has a better fit hence the estimate were used for subsequent projection of biomass in three scenarios viz. Scenario I (Fishing hours retained at present level), Scenario II (Fishing hours reduced by 20% of present level) and Scenario III (Fishing hours increased by 20% of present level). The present level of fishing intensity will maintain the present population but in case of Scenario II, by 2025 the biomass level be at par with the maximum estimated during the study period (2007-18). In case of Scenario III, the biomass by 2025 will decline to lowest level of last 5 years.

# Present status and trend of marine prawn fishery in India

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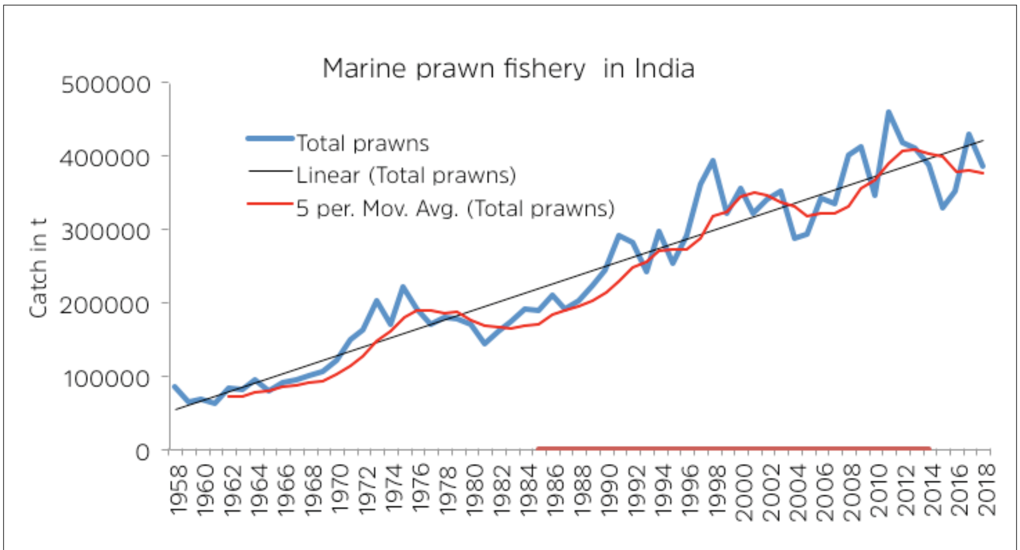
Among the various marine fishery resources, prawns occupy the most important position because of its high export value. India is the world's largest exporter of prawn with the export value of $2.6B in USD raising India's market share in global prawn export to 19.2% in 2018. The ever increasing demand of prawns in export market makes the fishery more and more lucrative and charming. The prawn fishery of India during 1958-2018 ranged from 62,768 t to 4,60,026 t with an average of 2,38,764 t. The highest catch was in 2011. In 2018 half of the catch was formed by penaeid prawns and the other half was formed by non-penaeid prawns. The catch formed around 10 to 15 % of the total marine catch with an average of 12%.

Though the catch show a steady increase over the years, the average catch of 2010-2015 showed only five times increase when compared with that of 1960-65 irrespective of the rapid changes in fishing effort. The different developmental stages which augmented the prawn fishery especially deep sea prawn fishery were the introduction of trawlers succeeded by multiday-trawlers.

Now, around 65% of the penaeid prawn catch was landed by multiday trawlers followed by single day trawlers (17%) and mechanised dol netters (6%). In the case of non-penaeid prawns 68% of the catch was landed by mechanised dol netters followed by multi-day trawlers (16%) and single day trawlers (7%). The past ten years data showed that the highest penaeid prawn catch was from Kerala (17%) followed by Maharashtra (16%), Gujarat (15%) and Odisha (13%). In the case of non-penaeid prawns the highest catch was from Gujarat (55%) followed by Maharashtra (27%), west Bengal (7%) and Odisha (5%). Almost the entire deep sea prawns were



caught by multi-day trawlers and Kerala ranked first in its landing forming 67% in the last 10 years followed by Tamil Nadu (16%) and West Bengal (12%).

Among the penaeid prawns, the dominant species landed along Indian coast during 2007-17 were *Parapenaeopsis stylifera* (18.3%) *Metapenaeus dobsoni* (17.7%) followed by, *M. monoceros* (9.3%), *Solenocera crassicornis* (8.3%), *M. affinis* (6.9%), *Penaeus semisulcatus* (4.5%) and *P. indicus* (4.1%).

About 77% of the inshore non-penaeid prawn catch was constituted by *Acetes* spp. followed by *Nematopalaemon* sp. (20%).

Among the deep sea prawns, *Plesionika* spp. (33%) dominated followed by *Heterocarpus* spp. (29%) and *Aristeus* spp. (19%).

Though the size of penaeid prawns in the commercial catch ranged from 10 mm to 370 mm the mean size of the catch varied between 53 mm and 248 mm. However, the percentage of juveniles in the catch was considerably high. Females dominated in most of the species. Majority of the species spawned throughout the year with two peaks. The smaller mesh sizes in shrimp trawlers and indiscriminate fishing soon after the fishing ban were the major factors affecting the penaeid prawn fishery in India.

# Conflicts over fishing space: management complexities in the set bagnet fishery (dol net) of north-eastern Arabian Sea

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In the northern Arabian coast of India, along the coasts of northern Maharashtra and southern Gujarat there exists a specialized fishing practice using set bagnet (SBN) at 10-70 m depths in the sea, locally called as "*Dol*" net fishing in Maharashtra. Fishing is conducted by tying nets to poles vertically fixed to the sea bottom. Several variants of set bagnets are in use in this region even though the basic operation is the same. As per mutual understanding among the coastal villagers who use different types of crafts and gear, there are specific, non-demarcated areas conventionally reserved for SBN fishing. The operational areas in the near-shore like estuaries or near to coastal villages are mostly pre decided and mutually agreed. In this study, we analyzed the *dol* net (SBN) fishing data from 1991-2018 from Maharashtra. The results indicated that catch rate varied with location of *dol* nets. The catch rate of set bag nets operating in the near-shore area was about 160 kg/unit while for the offshore unit it was 289 kg/unit. In both the locations the major catch was non-penaeid prawns (47.7%) followed by Bombay duck, *Harpadon nehereus* (18%). Currently, there are no operational guidelines on SBN fisheries except for boat registration and necessary formalities as required for fishing. Fixing of permanent/semi-permanent structures in the sea is not formally regulated. In some places, the bagnet locations/stakes/poles (known as *Sus* or *Kav*) are managed by fishermen societies or friends/family network. The fixed stakes in a particular location is owned by a family or individuals, which can be sold, leased, rented or shared for operation. With the increasing mechanization in Indian coasts and technology innovations, both the number of fishing vessels as well as fixed stakes/poles have increased substantially in the region leading to increased conflicts and clashes at sea, over limited operational area for fishing. As there is no information about the locations, number of the stakes in the sea and the number of nets used during each trip with the authorities, the management of SBN fisheries is challenging. In addition to it, addressing the high juvenile bycatch in SBN (60-96%) is another major concern. SBN fishery management will not be an easy task unless proper co-operation and co-ordination at all levels of government and stakeholders are ensured, besides political will to address the concerns of fishery management and ecosystem health.

# Length-weight relationship and relative condition factor of spotfin flathead, *Grammoplites suppositus* caught off Cochin, southwest coast of India

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Length-weight relationship and condition factor are important fishery management tools for understanding the biological changes in fish stocks and thereby helps in developing effective management measures. It also helps to monitor the status of fish stock and morphological disparity of the same species in different areas and season. The relative condition factor generally specifies the physiological state of the fish including its reproductive ability, developmental stages and physical well-being. Condition factor has also been used as an index of age, growth rate and feeding intensity. Spotfin flathead, *Grammoplites suppositus* (Troschel, 1840) is a demersal fish belonging to the family Platycephalidae, distributed in the marine waters of tropical Indo-West Pacific regions. The length-weight relationship (LWR) and relative condition factor of *G. suppositus* were studied based on 216 specimens sampled from trawl landings at Cochin during May 2017- April 2019. The total length of the fishes ranged between 180 to 310 mm and the total body weight ranged between 35 to 285 g. The LWR of pooled sample was calculated as $W=0.0027\ L^{3.306}$. It showed a positive allometric growth with b value of 3.306 indicating that the fish grows faster in weight than in length. LWR was highly significant ($p < 0.001$) with coefficient of determination ($r^2$) value of 0.896. The mean relative condition factor (Kn) values ranged from 0.958 to 1.008 which is close to unity indicating good growth condition. An increasing trend in the relative condition factor with the size of the fishes was observed and the highest Kn value was in the size range of 270-310 mm. This is the first report on LWR and relative condition factor for *G. suppositus* from Kerala waters.

# Fished taxa species diversity along the Indian coast and its significance in relation to the harvest of marine fishery resources

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The marine fisheries in India depends on its highly diverse marine living resources contributing to the landings along its coast. There are more than 1200 species reported in the catch by various types of fishing vessel-gear combinations belonging to the mechanized, motorized and non-mechanized sectors. As per the marine fisheries census 2016 there are 42,656 mechanized fishing crafts, 95,957 outboard fishing crafts and 25,689 non-mechanized fishing crafts operating from 1265 marine fish landing centres distributed along 9 maritime states and two union territories. Information about diversity in the fished taxa and the dynamic changes taking place in the diversity is important for fisheries management leading to sustainability of this natural resource.

Here, the changes in species diversity in the fished taxa along the Indian coast during the 12 year period 2007-2018 is examined using information from the individual species level database available in the National Marine Fishery Resources Data Centre (NMFDC) of ICAR-Central Marine Fisheries Research Institute (CMFRI). State wise data on individual species level landings in each year formed the basis for calculation of average taxonomic distinctness (DELTA+) and variation in taxonomic distinctness (LAMBDA+) using Primer version 5.2.9 software. Low DELTA+ values indicate low taxonomic diversity and stressed biodiversity.

The number of species landed in each maritime state in different years was also generated from the database.

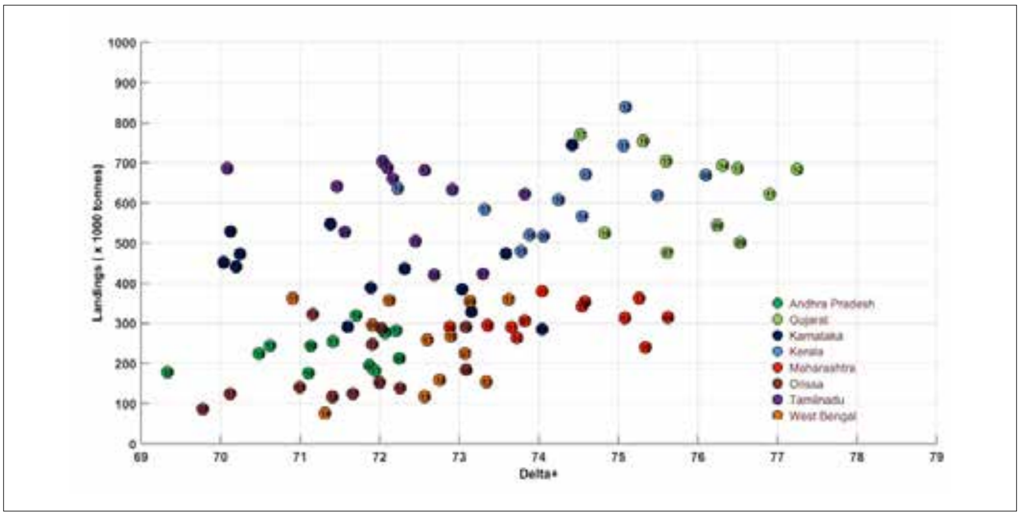


Figure: scatter plot of total landings in each year pertaining to different maritime states against corresponding DELTA+ values

During the period, there were 1233 species landed along the Indian coast with maximum in Tamil Nadu (878) followed by Kerala (771) and the least was 316 in West Bengal. In the recent years, the total annual landings was maximum in Gujarat followed by Tamil Nadu and Kerala though the total number of species landed in Gujarat during the 12 year period is 437 which is roughly half of that for Tamil Nadu. The scatter plot of total landings in each year pertaining to different maritime states against corresponding DELTA+ is given below. A regression analysis of landings against DELTA+ revealed significant positive regression coefficient ($p > 0.001$) of DELTA+ on landings indicating that higher species diversity encourage higher landings. An upward trend is visible in the plot with a bit of scattering which indicates this conclusion.

Few other observations revealed by the study are (i) though the number of species landed in Gujarat is comparatively low the diversity in fished taxa is high for this state (DELTA+ > 74). Thus the resources landed in Gujarat are taxonomically more distinct than that in other states. (ii) In most of the states there is a decline in the diversity in the fished taxa in the recent years indicating movement towards stressed biodiversity and (iii) The fluctuation in taxonomic diversity is high in Maharashtra even though the landings in this state is not much varying.

# Biometry of flathead sillago *Sillaginopsis panijus* (Hamilton, 1822) (Perciformes: Sillaginidae) in the north-western Bay of Bengal

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Biometry, length-weight relationships (LWRs) and length-length relationships (LLRs) of *Sillaginopsis panijus* (Hamilton, 1822) were investigated in the north-western Bay of Bengal. Altogether 622 specimens were collected between August 2018 and September 2019 from various fishing gears: trawls (30-35 mm mesh size), gillnets (15-55 mm mesh size) and shore seines (7-15 mm bag mesh size) along Odisha coast. The total length and weight ranged 7.8-40.3 cm and 2.9-506 g, respectively. The length range for males was found to be 11-33.2 cm TL and females 9.9-40.3 cm TL with the mean length of 22.92± 4.45 cm TL and 26.35± 5.43 cm TL, respectively. Male constituted 9% (n = 56), female 74% (n = 460) and indeterminate 17% (n = 106) in the population. The length frequency analysis of both the sexes of *S. panijus* did not show any normal distribution based on Kolmogorov-Smirnov test ($p<0.05$), but the Mann-Whitney U-test ($p<0.01$) showed significant differences in the length frequency distribution of male and female. The LWRs was established as $W=0.0048L^{3.059}$ for males, $W=0.0032L^{3.185}$ for females and $W=0.0039L^{3.128}$ for pooled individuals, indicative of positive allometric growth pattern in all the cases. All the LWRs were highly significant ($p<0.001$, $r2\geq0.977$). The analysis of variance (ANCOVA) revealed a significant difference in intercepts (a) and slopes (b) of the regression lines ($F$ = 1582.68, $df$ =514, $p<0.05$) between the sexes. Hence, the LWRs were established separately for both the sexes. The calculated 't' value of the students' t-test was found to be significant at 5% level. Morphometric variables showed a significant correlation with highest coefficient of correlation ($r$) was observed for total length against fork length (0.999) and lowest for head length against eye diameter (0.951). The fin formula can be expressed as D1 X, D2 I + 24-28, P 17-22, V I + 5, A II + 25-27, GR 2-3/6-9. The basic biological parameters, LWRs which can be easily estimated but remain absent or poorly studied for several fish species in the Indian waters. The study provides the first detailed insights into the biometric analysis of *S. panijus* in the Indian waters which will be helpful as baseline information for subsequent biological and population based studies in the studied area or nearby ecosystem.

# Breeding season induced morphomertic variations in obtuse barracuda, *Sphyraena obtusata* Cuvier, 1829 from the commercial fish landings at Vizhinjam, Kerala, India

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Obtuse barracuda (*Sphyraena obtusata* Cuvier, 1829) is one of the common species of barracuda in the landings from traditional fishing crafts and contribute much to the total landings along southern Kerala. According to CMFRI (2018) reports, 45.3% of total barracuda catch (2057 t), were comprised of *S. obtusata* among five common barracuda species in the landings. Obtuse barracuda was available throughout the year even during the trawl ban season as it was caught in traditional fishing gears like gillnet, boat seine, hooks and line, *roll vala* and drift net. Since all size groups were available throughout, the present study was carried out to find out the morphometric variations of the species in respect to its breeding season. A total of 10 morphometric variables including weight were recorded monthly from the fishes landed at Vizhinjam fish landing centre (Thiruvananthapuram District, Kerala) for two years from January 2017 to December 2018.

Analysis of variance (One Way ANOVA) along with post hoc comparisons (DMR test) of the morphometric variables comparing breeding seasons (pre spawning, spawning and post spawning) revealed significant ($P < 0.05$) variations in weight, head length, snout length, snout to pre-nostril length, inter-dorsal length and caudal peduncle length in total population (N=429). Seasonal comparison of male population (n=176) alone also showed significant difference similar to total population except head length and female population (n=253) registered significant difference in only three variables like snout length, snout to pre-dorsal length and caudal peduncle length. Biometric ratios like TL: SL, SnL: SL, Sn-Plvc: SL, IntrDrsl: SL and CPL: SL ratios showed significant variations between the seasons. Principal component analysis extracted three ratio variables, TL: SL, SnL: SL and CPL: SL as contributing factors for breeding season variations. Rate of growth in terms of biometric ratios showed more fluctuations than absolute morphometric variables, which clearly emphasizes the growth rate shift from length to weight dependency during breeding season. Information on morphometric variations can be used for fishery stock management and/or regulations for sustainable fisheries as well as to understand the fish biology and population dynamics.

# Trophodynamics of Big-jawed jumper *Lactarius lactarius* Bloch & Schneider, 1801 off Malabar Coast

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The trophodynamics of the big jawed jumper, *Lactarius lactarius* (Bloch & Schneider, 1801) from the fish landings of the Malabar region, southwest coast of India was studied during 2018 by examining the specimens collected from various fish landing centers. Finfishes were the preferred prey with an index of relative importance (IRI) of 46.82% followed by crustaceans (IRI 27.56%). Among finfishes, *Stolephorus* spp. (IRI 31.92%) found to be predominant prey and *Acetes* sp. (IRI 25.21%) in crustaceans. The secondary food items ingested were fish scales (7.36%), *Bregmaceros* sp. (IRI 1.2%), other shrimps (IRI 1.09%), mysids (IRI 0.94%) and squids (IRI 0.58%). The highest value of gastro-somatic index was obtained in September (2.60+1.42) and the lowest in July (0.87+0.54) with an annual average of 1.69+1.64. The highest level of vacuity index was observed in July (57.14) and the lowest in October (16.17). Feeding intensity was lower in juveniles & larger adults (an average of 46% of them exhibited empty and trace stomachs) and was high in smaller adults (73% of moderate and full stomachs). In juveniles, the diet comprised chiefly of crustaceans (65.6%), smaller adults exhibited preference towards both crustaceans (40.1%) and finfishes (33.5%) and the larger adults exhibited higher preference towards finfishes (60.7%) indicating that as the big-jawed jumper grows, it tends to be an active piscivore.

# Passive geo referencing of available historic data for reconstruction of spatial and temporal dynamics of mechanized trawl fishery in Gujarat

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Marine ecosystems and resources are under severe threat due to increase in pollution, coastal development projects, natural calamities and the fishing activities. Fishing especially trawling has a detrimental impact on the biodiversity, all the more if the trawling is made in ecological sensitive habitats (coral reefs, sea grass beds, mangroves, etc.). In addition, trawling can lead to overfishing of commercially exploited resources, juvenile and spawner's, increased exploitation of by-catch and threatened species. Our country is far behind in the spatial mapping of the marine fishery resources and fishing grounds and is still a nacent field in India as compared to other developed countries. Further it is all the more complex in India due to the unorganized fishery structure and as laggard in technology adoption and diverse in both resources and crafts. In this context, the present piece of work provides a way to map the fishing grounds with the available historic fishery data to understand the spatial and temporal spread of fishing activity. This passive geo-referencing method was used to map the fishing pattern of Mechanized Trawlers, MTN (operate for single day)using the available fishery data for 12 fish landing centers in Gujarat (N=2678). The distance of the fishing grounds from the landing center/barmouth ranged from 4 to 75 km (mean ± sd; 18.06 ± 9.86 km). The average depth of operation was 26.57 ± 9.0 m (5 to 80 m with an inter quantile range of 12 m). The catch rates (Catch Per Unit Effort, CPUE in kg/hrs) were higher In the MTN than the other fishing crafts due to the active fishing and retention of whole exploited catch (negligible discards). The catch rates recorded in the study period ranged from 17 to 689 kg/hr (mean ± sd; 86.36 ± 91.20 kg/hr with an inter quantile range of 63.30 kg/hr). The catch rates were highly dynamic in nature both in spatial and temporal scales. One-way ANOVA infer the significant variations in catch rates among different quarters ($p<0.005$). The mean CPUE was highest during the quarter I (101.80 kg/hr), followed quarter II (94 kg/hr), quarter III (82.65 kg/hr) and quarter IV (72.54 kg/hr). The catch rates were comparatively higher in the quarter I due to the significant contribution by the fishery resources like non-penaeid prawns, croakers, ribbonfishes, etc. The non-penaeid contribution by the MTN was visible in a target mode during February to May months, which requires a focussed investigation and management interventions. The information on fishing practices is missing in various development plan approvals in India, which often lead to unanticipated conflicts in the sea, competing for space and resources. The spatial intensity of the fishing crafts depicted that the fishing pressure in the different fishing grounds, continuation of effort in such areas may lead to steno-productivity zones due to the depletion of resident resources and stability of ecosystems. In future, the resource-wise catch composition of the fishing ground data can be generated to understand the spatial and temporal abundance of the resources, which in turn can be used to comprehend the migration patterns and environmental impacts on the resources

# Long-term changes in the mean trophic index of fished taxa in Kerala

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Ecosystem changes due to fishing are frequently complex, reflecting change in processes at multiple levels. Trophic decline, combined with decreasing biomass, leads to changes in the structure of ecosystems. Fishing activities can alter the structure of marine food webs by the selective removal of some species. The changes in the marine food webs along the coastal waters Kerala were assessed, based on estimates of the mean trophic level (MTL) and Fishing in Balance index (FiB) during 1981-2018. The Mean Trophic levle is one of the most operational indices available for capturing the effects of fishing at the ecosystem level. It measures overall ecosystem health and stability, but also serves as a proxy measure for overfishing. The mean trophic level (TrLi) for a given year i was estimated by multiplying the landings (Yi) by the trophic levels of the individual species/groups j, then taking a weighted mean, that is,

$$T_r L_i = \frac{\sum_{ij} TL_j Y_{ij}}{\sum_j Y_{ij}}$$

where TL*j* is the trophic level of individual species/group *j*, *Yij* the landings of that species/group in year *i*.

The FIB index for any year i in a series is defined by:

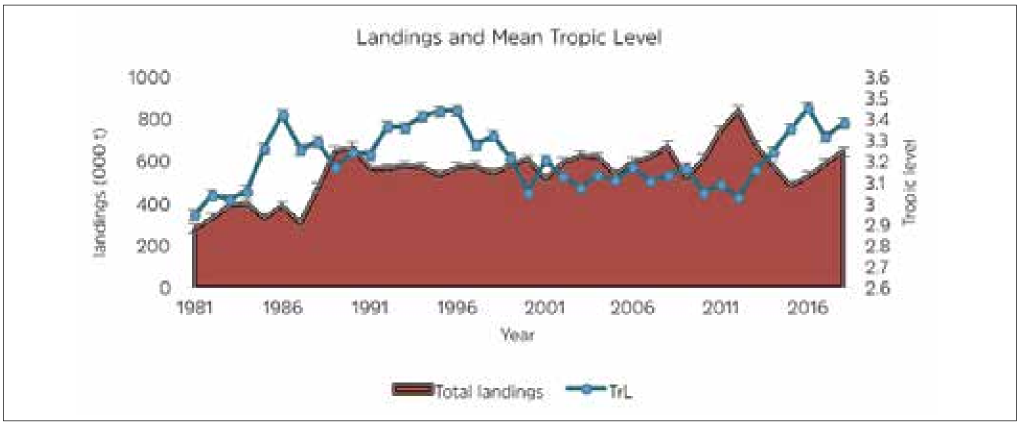
$$FiB = log\left(Yi * \left(\frac{1}{TE}\right)^{TrLi}\right) - log\left(Y_0 * \left(\frac{1}{TE}\right)^{TrLo}\right)$$

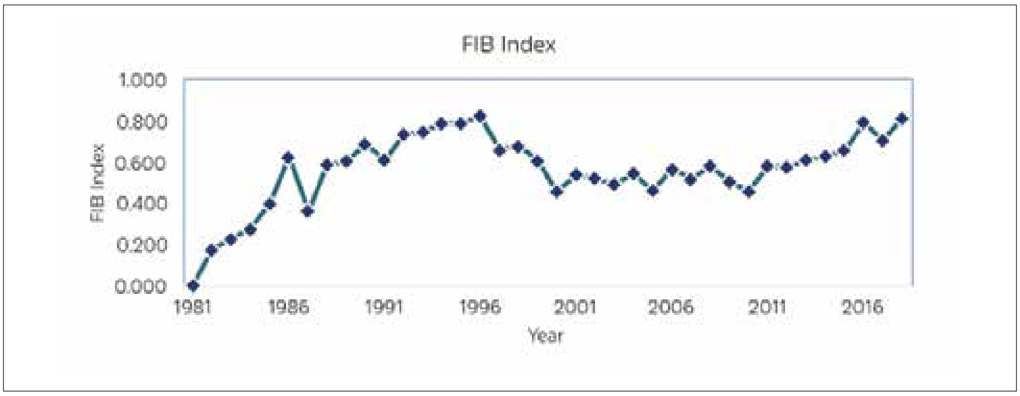
where Y is the landings, TE the transfer efficiency (the fraction of production passing from one TL to the next higher TL), TrL the mean trophic level in the catch and 0 refers to any year used as a baseline. The FiB index indicates whether fisheries is balanced in ecological terms. It relates the catches and average trophic level in a given year to the catches and average trophic level in an initial year to determine whether the change in mean trophic level is compatible with the transfer efficiency of that region.

The landings along the Kerala coast showed an increase from 0.27 million tonnes in 1981 to 0.64 million tonnes in 2018 with a peak of 0.84 million tonnes in 2012. During the initial years the landings showed abrupt fluctuations with slight increase upto 1984, followed by a decline for next few years. However, the MTL increased from 2.94 to 3.41 during this period

There was substantial increase in the landings from 1989 onwards with average landings of 0.6 million tonnes. The MTL showed an upward trend during 1990-1996, with an average of 3.35 and witnessed small fluctuations in the subsequent period till 2012. The Mean trophic index was maximum during 2016, when the contribution of fish groups in low-trophic categories like oil sardine, penaeid prawns etc. were low in the landings.

A fishery is said to be fishing in balance when *FiB* is equal to zero and when *FiB* > 0, implies that the fishery has expanded geographically. The FiB index was maximum in 1996, which coincides with the introduction of multiday fishing in this region. In many of the highly productive ecosystems of the world and particularly in upwelling regions, there tends to be a crucial intermediate trophic level occupied by small, plankton-feeding pelagic fish that is typically dominated by only one, or at most a few, species. The high environmental variability of upwelling systems, generating large fluctuations of landings and biomasses of a few dominant species, like oil sardine, open the possibility 'fishing through' or 'fishing down' the food web.


Landings and Mean Tropic Level
landings (000 t)
Tropic level
Year
Total landings
TrL


FIB Index
FIB Index
Year

# Advisory on stock assessment periodicity for exploited marine fisheries resources along the Indian coast

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One of the key roles of stock assessment is to understand the dynamics of fisheries. This is because biological resources and the environment are dynamic not static. Further, fisheries will necessarily respond dynamically over time to management actions as well as to external factors such as the environment. Life history characteristics play an important role in assessing populations and managing stocks. They provide information on how a species grows and develops, senses its environment, captures food, avoids predation and reproduces. Understanding these dynamics are essential to make an estimate fish abundance, fishing-related impacts and other factors to describe the past and current status of a fish stock which is the ultimate role of stock assessment.

The need for more timely and comprehensive stock assessments has increased greatly for management of depleted or overfished stocks. It also depends on the life span and of those species which are economically most important and which forms majority of the fisheries biomass. An estimate of the maximum age or life span (time for growing upto 95% of asymptotic length) that a fish can attain is 3/K, where K is the curvature parameter or growth rate coefficient in von Betralanffy growth equation. The K values estimated from earlier stock assessment studies for 186 species were used as input to determine the life span of different species. This information formed the basis for determining the periodicity of stock assessments (stock assessment cycle). The following criteria were followed to arrive at stock assessment cycles and related aspects.

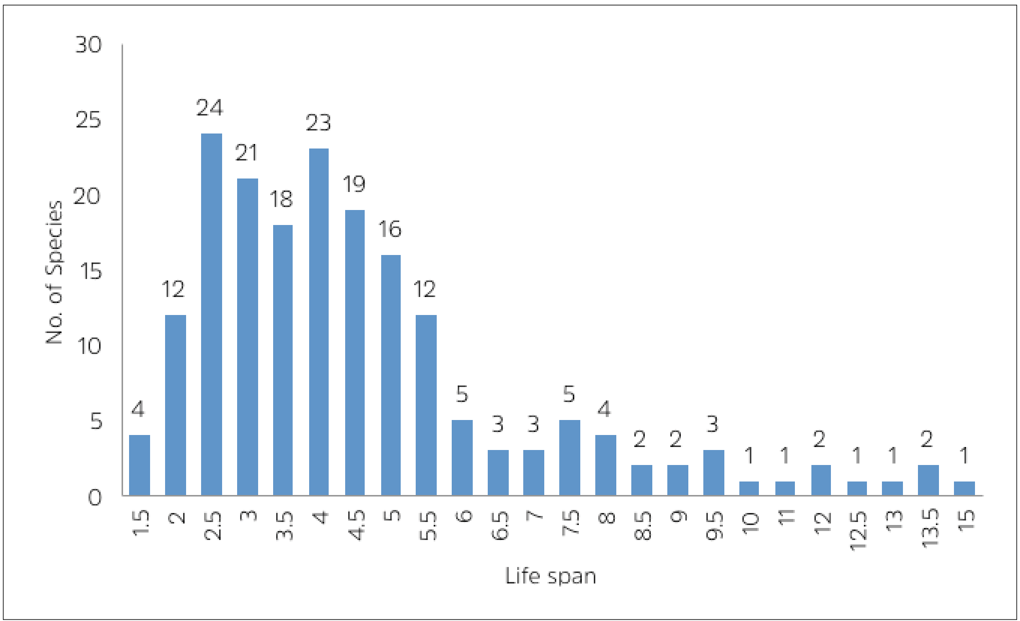
(i) The stock assessment for fishes having a life span up to two years should be carried out every year (annually). Cephalopods, shrimps, crabs and small pelagic fishes mostly come under this category.

(ii) Biannual i. e. every two year assessment should be done for the stocks having a life span from 2 to 4 years.

(iii) The assessment frequency for the stocks having a life span from 4 to 6 years should be at every three years interval.

(iv) The stock assessment should be done once in five years for all fishes with more than 6 years of life span

| Assessment Frequency | Life span (years) | No. of Species |
|---|---|---|
| Annual | ≤2 | 16 |
| Biennial | >2 and ≤4 | 87 |
| Triennial | >4 and ≤6 | 52 |
| Quinquennial | >6 | 31 |




This advisory needs to be taken into consideration by stock assessment agencies/ institutes in deciding the stock assessment periodicity. This information is available for each region/resource along the Indian coast

# Impact of growth overfishing on two species of pelagic sharks caught from eastern Arabian Sea

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India is one among the major shark fishing countries at global level and currently stands at the second position with high domestic utilisation in the form of shark meat. The shark fishery along the coast of India is predominantly supported by about 20 species. As there is a blanket ban on the trade and export of shark fins from India, the most valued part of sharks in the country is their meat, with a preference to small sized individuals in the domestic market. During 2017-18, 20 species of sharks were landed in Kerala, of which, the silky shark *Carcharhinus falciformis* formed the dominant species and *C. falciformis* along with the graceful shark *C. amblyrhynchoides* together formed 50% to the shark landings of the region. Most of these catches, comprising high proportion of juvenile individuals, landed in Kerala were sold either in fresh or dry fish markets. International Union for Conservation of Nature (IUCN), in their assessment in the Red List of Threatened species included *C. falciformis* as 'Vulnerable' whereas *C. amblyrhynchoides* was assessed as 'Near Threatened'. For the present study to assess the impact of growth overfishing which targets undersized individuals and juveniles of these species, samples were collected from the longline and gillnet fishery from the eastern Arabian Sea. Cochin Fisheries Harbour (Lat. 09°56'327"N, Long. 76°15'764"E), which is the major shark landing centre of Kerala, southwest coast of India was selected for regular sampling. The size composition, sex and price composition of the landed specimens were analysed based on samples collected in a fortnightly basis from January 2017 to December 2018 during the landings from commercial fishing boats. The price structure of both juvenile and adult specimens of the sharks were collected at the point of first sale.

During 2017-18, 87% of the landings of *C. falciformis* and 73% of *C. amblyrhynchoides* comprised of juveniles below the reported size at first maturity, signifying the gravity of growth overfishing of dominant species of pelagic sharks along the coast. The expected economic loss due to the harvest of these two species were estimated based on the bio-economic model, incorporating growth, mortality and length weight parameters as well as the differential ratio of juvenile and adult prices of the species. The average annual loss due to growth overfishing of *C. falciformis* was estimated as ₹125.4 crores and that of *C. amblyrhynchoides* at ₹17.3 crores. The economic loss during the entire period of study due to the harvest of the juveniles of the two species was estimated at ₹285.4 crores. However, the estimated loss due to the juvenile harvest of these pelagic sharks were lesser compared to that of their most teleost counterparts due to the negative differential ratio between adult and juvenile prices owing to higher demand for juvenile shark meat in the local market. Nevertheless, the biological impact of growth overfishing of this ecologically vulnerable group of fishes is much higher than that of the other commercially important group of fishes. As several shark species around the world are of great conservation concern due to their innate life history characteristics, the findings of the present study is important to regulate or curtail extensive juvenile harvest of this economically important and ecologically sensitive group of fishes to ensure sustainability of the resource.

# Morphometrics and length-weight relationships in *Portunus sanguinolentus* (Herbst, 1783) landed off Cochin, South India

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*Portunus sanguinolentus* is widely distributed all along the Indian coast and the most dominant marine crab landed in the country. In Kerala also, species share is maximum in the marine landings and recorded an average landing of 1200 tonnes during 2007-2018. The bulk of the catch is contributed by trawlers and the species is mainly fished from 20-30 m depth zone. It grows to a maximum size of 20 cm in carapace width (CW) and the estimated life span is approximately three years.

Information about individual body weight-length/width relationships in populations is important for estimating the population size of a stock, specifically for the purpose of its exploitation. Hence, the interrelationships between various morphometric characters, viz., Carapace Width (CW) and Length (CL) and Chelar Propodus Length (CPL) and Height (CPH) in males, as well as Carapace Width and length and Abdominal Width (AW) and Length (AL) in females, were estimated using a total of 2476 male and 2965 female crabs. The Carapace Width/Length-Weight relationship was studied in both sexes on a total of 5595 crabs using the allometric growth equation. The allometric relationships between the characters of this set suggest that most relationships are positive and highly significant ($P \leq 0.01$). The details are given in the Tables 1 & 2. The 'b' values for carapace width-weight in males (55-171 mm/CW), females (54-170 mm/CW) and pooled were 2.9657, 2.8028 and 2.8914 respectively (Figs. 1-2). The results show an isometric growth pattern for males and considerable deviation from isometric growth in females and when all sizes are pooled. An analysis of covariance indicates that there is a significant difference between sexes ($P \leq 0.01$) with respect to carapace width-weight relationship. The results will be useful in comparing the different stocks of the same species at different geographical locations and helpful for suggesting management options for the optimum exploitation of the Three-spot swimming crab along the Indian coast.

Table- 1. Allometric equations and correlation coefficient (r) values between different variables in males of *Portunus sanguinolentus*

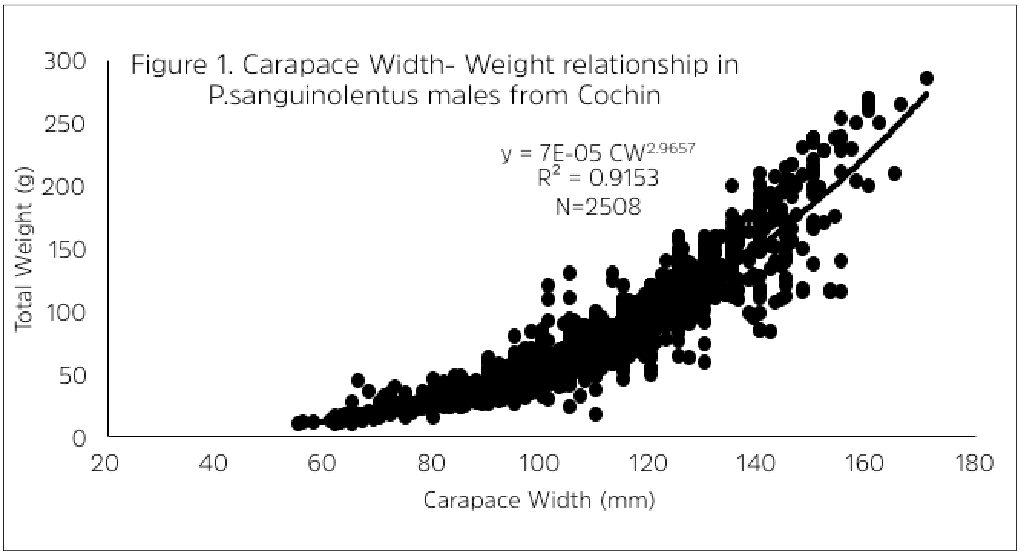
| Independent variable (x) | Dependent variable (y) | Allometric growth equation (y = a + bx) | 'r2' value |
|---|---|---|---|
| Carapace width (CW) | Chelar propodus length (CPL) | CPL = -15.697+ 0.7098 CW | 0.8343* |
| Carapace width (CW) | Chelar propodus height (CPD) | CPH = -1.54+ 0.1552 CW | 0.6792* |
| Carapace length (CL) | Chelar propodus length (CPL) | CPL = -11.938 + 1.5405 CL | 0.8141* |
| Carapace length (CL) | Chelar propodus height (CPH) | CPH = -1.095 + 0.33456 CL | 0.6875* |
| Chelar propodus length (CPL) | Chelar propodus height (CPH) | CPH = -3.2574 + 0.1955 CPL | 0.655* |

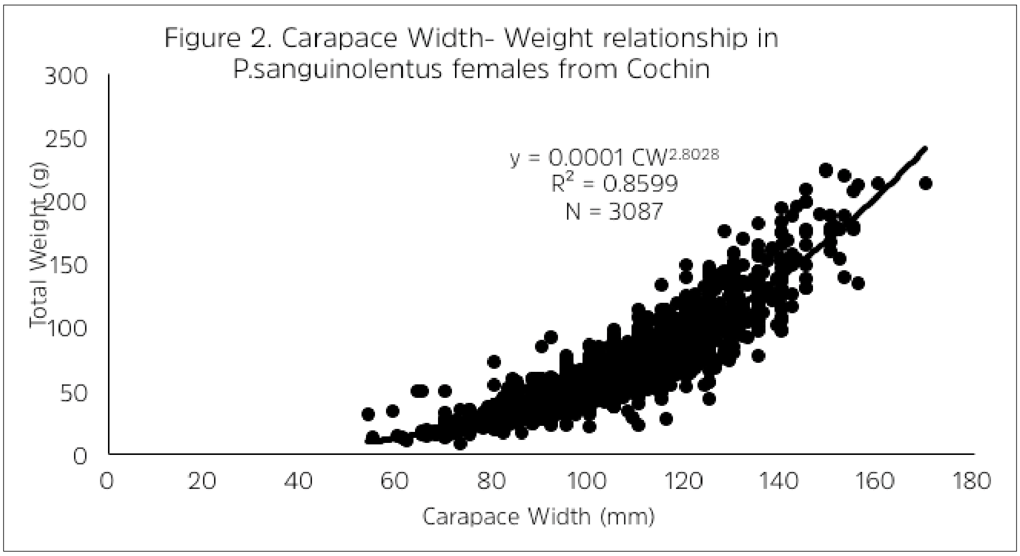
* Indicate high positive allometry significant at 1% level.

Table- 2. Allometric equations and correlation coefficient (r) values between different variables in females of *Portunus sanguinolentus*

| Independent variable (x) | Dependent variable (y) | Allometric growth equation (y = a + bx) | 'r2' value |
|---|---|---|---|
| Carapace width (CW) | Abdomen width (AW) | AW = -8.8967 + 0.3854 CW | 0.7731* |
| Carapace width (CW) | Abdomen length (AL) | AL = -1.2091 + 0.3415 CW | 0.6791* |
| Carapace length (CL) | Abdomen width (AW) | AW = -3.8345 + 0.7657 CL | 0.7024* |
| Carapace length (CL) | Abdomen length (AL) | AL = -3.4255 + 0.6744 CL | 0.6087* |
| Abdomen width (AW) | Abdomen length (AL) | AL = -2.5553 + 0.8338 AW | 0.6188* |

* Indicate high positive allometry significant at 1% level.



# Fishery and stock assessment of silver pomfret *Pampus candidus* (Cuvier 1829) from north-eastern Arabian Sea

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Pomfrets of family Stromateidae (Perciformes) locally called as "*paplet*" are one of the most traded, commercially important and preferred table fishes in Maharashtra. The taxonomy and nomenclature of Stromateidae fishes are still unresolved and a recent study by Divya *et al.*, 2019 stated that the silver pomfret in west coast of India is *Pampus candidus* (Cuvier, 1829) and not *P. argenteus* (Euphrasen, 1788).

Pomfrets are caught as bycatch and in targeted fisheries, with diverse crafts and gears in Maharashtra. During 2008-2018 period the average catch of stromateids were estimated at 4,192 tonnes and it contributed 0.74% to 2.47% of total marine capture fishery in Maharashtra, where *Pampus candidus* formed 93.3% of fishery and 6.7% by *Pampus chinensis*

In Maharashtra, the catch of silver pomfret has shown a decreasing trend since 1980, where the average annual catch during 1962-1976 was 8,312 tonnes, during 1991-2000 it fell to 6,592 tonnes and during 2001-2010 the landing was 4,479 tonnes. During 2010-2018 the landing further fell to 4154 tonnes. The historical maximum landings recorded was 17,979 tonnes in 1976. With the changes in the pomfret trade in domestic and international market, fishing systems and operations, ways are also modified to specifically target pomfrets, there by affecting the stock in the northern Arabian Sea. Pomfret is considered as a status and luxurious food symbol, which is also paving the way to the market acceptability of juvenile pomfrets which is a worrying trend. Growth overfishing is predominant in the region mostly by set bagnet (*Dol* nets) and trawls which is already impacting the fishery economics. Length frequency-based (2015-2018) stock assessment undertaken using TropFishR shows that *P. candidus* is over-exploited in Maharashtra and management interventions are urgently needed.

# Reproductive biology and recruitment dynamics of brown mussel, *Perna indica* along the Vizhinjam coast of Kerala

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Mussel fishing is an important source of income for the fisherfolk especially divers in the Vizhinjam to Kovalam region of Kerala and along the southern tip of Tamil Nadu Coast. The average annual production of brown mussel *Perna indica* from Vizhinjam- Kovalam bed for the last decade is 2009-2018 is 661.8 tons. The price of mussel has gone from 50 paisa to ₹4/ shell-on mussel. Biology and recruitment dynamics of species are of importance for the management of Fishery. Fishery samples of brown mussel, *P. indica* were collected from 2017 to 2019 from Vizhinjam Coast of Trivandrum, Kerala. Periodic sampling was done on the bed to collect the spat for growth measurements. Maturity stage of mussels were analysed by taking gonad sample and observing the gonadal smear under microscope. The stages of maturity were assigned as 1) Immature, 2) Maturing 3. Ripe and 4. Spent. The Spawning season of brown mussel was observed from May and it extended till August. The peak spawning was during June to August, coinciding with the southwest monsoon. Spat fall began by July and extended till September, when the spat attained about 2mm in length and dense settlement of spat was observed from July onwards. Mussel population in the region were observed to be in spent condition in September. Sex ratio, spawning season, settlement and growth of brown mussel spat is presented in this paper.

# Diet composition of Spadenose shark, *Scoliodon laticaudus* Muller & Henle, 1838 off Gujarat

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Spadenose shark is a common species in the tropical Indian and western Pacific Oceans, where it forms large schools in shallow water. Shark landing of Gujarat is mainly contributed by *Scoliodon laticaudus* (83.3%) followed by *Carcharhinus* sp. (14%). The information on the dietary composition of a species is essential for understanding the role of elasmobranchs in marine ecosystems and the impact of elasmobranch predation on economically valuable or endangered prey. A total of 1277 specimens of *S. laticaudus* were collected on a weekly basis from different landing centres of Gujarat from 2012-2014 and subjected to biological analysis which revealed that the shark forages on diversified prey items which were pooled into 3 distinct groups i.e., teleosts, crustaceans and mollusks. The relative importance of each prey item as well as their affiliated groups was evaluated by using the dietary coefficient (QI) and the index of relative importance (IRI) for *S. laticaudus*. Crustaceans (%QI=48.30; %IRI=54.71%) were found to be the dominant as well as preferential food items of *S. laticaudus* followed by teleosts (%QI=38.91; %IRI=36.06), which formed the secondary but dominant food item group. Mollusks (%QI=12.78; %IRI=9.24) constituted the secondary accessory food items for *S. laticaudus*. In crustaceans and teleosts major portion of the prey items could not be identified due to advance stage of digestion. However, a total of 12 genera of teleosts representing 10 families, 7 genera of crustaceans representing 5 families and 3 genera of mollusks representing 3 families could be identified.

The overall Shannon-Wiener index (H'), Pielou's index of evenness (J') and Margalef's index of richness (d) for the diet of different sexes and maturity stages of *S. laticaudus* were analyzed. Minor variation in the biodiversity indices were observed between the prey items of male and female sharks as well as juvenile and adult sharks of *S. laticaudus.* With highest variety of prey items, the dietary breadth of male adult sharks showed highest Margalef's index of richness and highest Pielou's index of evenness for the prey species. Thus the Shannon-Wiener index of biodiversity was highest for the gut content of male adult sharks. The biodiversity indices were low in the gut content of female adult sharks and the female juvenile sharks showed the lowest richness and evenness of prey items for the male juvenile sharks.

The index of relative fullness (IRF) of female sharks, though not significant (Mann-Whitney U test, $P > 0.05$), was found to be higher than that of male sharks. However, an ontogenetic shift in feeding behavior was apparent as juvenile sharks showed a significantly higher IRF compared to adult sharks (Mann-Whitney U test, $P < 0.05$). The adult male sharks were found to have significantly lowest (Kruskal-Wallis test, $P < 0.05$) IRF compared to the female adults as well as juveniles of both the sexes. On the other hand, the juveniles of female sharks showed highest IRF (Kruskal-Wallis test, $P < 0.05$) compared to the juveniles of male sharks as well as adults of both the sexes. Of all the shark specimens analyzed, 784 sharks were found to be positive for food contents in their stomach and remaining sharks were found to have empty stomachs, which resulted in an overall vacuity index of 38.61%. The vacuity index for female *S. laticaudus* was found to be higher than that of male sharks. The adult sharks showed lower vacuity index compared to the juvenile sharks. In case of female and male *S. laticaudus*, the adults showed lower vacuity index compared to the juvenile sharks. Mean number of prey per stomach of female was found to be lower than that of male sharks. However, the mean number of prey per stomach of juvenile sharks was found to be higher than that of adult sharks. Mean number of prey (MNP) was found to be highest in female juvenile sharks followed by male juvenile and male adult sharks. The lowest MNP was observed in case of female adult sharks. Visible differences in prey preference was also noticed as the relative importance of different prey groups was found to be different among juvenile female, adult females, juvenile males and adult males.

# A new Outlook for Otolith

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Otolith, commonly known as "earstones", are hard, calcium carbonate structures mostly in the form of aragonite located in the inner ear cavity of all teleost fishes except shark, ray and lampreys. They serve as balancing organ and also aid in hearing. The three pairs of otolith present in bony fishes are Sagitta, Asteriscus, Lapillus.The main function of the sagitta and asteriscus were sound detection, converting sound waves into electrical signals and aid in the process of hearing. Lapillus is mainly involved in the detection of gravitational force and sound. The each pair of otolith located behind the brain have different shape. Among this Sagitta is the largest pair of otolith and mainly used for ageing purpose because these otolith are easiest to find out when dissecting a fish. However, in some fishes like Cypriniformes and Siluriformes, the lapillus is the largest. Otolith develops at the embryonic stage of their life and grows continuously throughout the life. They are not subjected to resorption even during starvation.These characteristics make them suitable for age estimation.They have been used to collect data about the taxonomy, age and growth and mortality are the important parameters in controlling the productivity of fish populations. Besides age and growth determination, otolith have been used in different fields such as fish biology, larval fish ecology, species identification, fish stock identification and environmental reconstruction of the fish habitat. The size and shapes of otolith varies with fish species. Each species of fish has a characteristic form of otolith, by which it can be identified. Some are thin and leaf shaped with frilly edges, some look like angel winged, some look like a tiny clam shell and some are round or lenticular with a pearly finish.

Otoliths have species specific shape and can be used as a taxonomic tool in species/stock identification

Our studies shows that otolith of many species have good lustre and have ornamental value. Response for the preliminary attempt in this direction was positive. Studies are in progress for identifying species having otoliths suitable for making jewel items. The scope for starting new ventures in this direction may create employment, especially for fisher women.

*Euthynnus affinis*

*Thunnus albacares*

Earrings made using otolith

# Studies on reproductive biology of the short neck clam *Paphia malabarica* (Chemnitz) from Muthalapozhi estuary, south Kerala, India

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Clams form a subsistence fishery in the Indian coastal regions, particularly along the southern states. Paphia malabarica, the short neck clam locally known as 'Poovankakka', is one of the nutritious and inexpensive food sources. Muthalapozhi Estuary is located in northern part of Thiruvananthapuram District, Kerala, where large-scale clam exploitation has started during the recent past. However, there has been no published record of reproductive studies of short neck clam in these areas and in order to formulate management strategies; information on the reproductive biology of this species is important. Also, knowledge on the reproduction of this species is a prerequisite to its breeding and rearing in hatchery condition. A study of the reproductive cycle of the short neck clam was undertaken from August 2018 and July 2019. Histological findings indicated that male shows the beginning of gametogenesis in July and female in June. Breeding season was observed during the period between October and January with peak spawning in November and December. The month of March showed more number of intermediates showing a peak somatic period. Condition index (K) ranged from 8.93 to 24.99. The highest K observed in March and Lowest in November and December.

# Food and feeding habits of two sciaenids, *Pennahia anea* (bloch, 1793) and *Nibea maculata* (bloch & schneider, 1801) from mandapam waters

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Food and feeding habits of two sciaenids namely donkey croaker, *Pennahia anea* (Bloch, 1793) and blotched croaker, *Nibea maculata* (Bloch & Schneider, 1801) were investigated based on the data obtained from 901 and 718 samples of each species respectively along the Mandapam waters during the period from January 2016 to December 2017. Analysis of fullness of stomach of *N. maculata* ranging size from 90-235 mm total length and 20.15-218.92 g body weight revealed 7.2% gorged, 6.17% full, 7.41% ¾ full, 29.01% ½ full, 18.52% ¼ full and 31.69% empty. The fishes recorded with poorly, moderately and actively fed stomachs during the study period were 51.21%, 36.42% and 13.37% respectively. Poorly fed stomachs were highest during February (96.77%), March (93.22%) and April (83.67%). Whereas during June and July more occurrence of moderately fed stomachs recorded (70.18% and 60.61% respectively)and maximum fishes with actively fed stomachs were noticed during July (38%) and August (33.33%). The calculated monthly mean values of vacuity index (VI) of *N. maculata* were highest during January to April with peak during March, 91.79%. Thereafter the index reduced to 0% during June and August. A gradual rise in the fullness index (FI) value was observed from 0 to maximum of 3.52 in August. Subsequently fare FI values within 2.09 to 2.75 were sustained up to November followed by a gradual decrease to 0 in February. The diet analysis based on index of relative importance (%IRI) revealed that *N. maculata* preferred crab (37.23%) as the main diet in all months followed by shrimps 30.12%, teleost fishes 25.49%, squilla 6.3% and bivalves 0.86%. Similarly the analysis of fullness of stomach of *P. anea* ranging size from 61-215 mm total length and 5.04-119.82 g body weight revealed that 6.68% gorged, 7.52% full, 6.47% ¾ full, 27.35% ½ full, 35.49% ¼ full and 16.49% empty stomachs. Poorly fed stomachs were highest in most of the months with peak during January (77.19%) and then steadily decreased to 0% in June. Correspondingly more fishes with actively fed stomachs were present in June (50%) and gradually decreased to 6% in October. Highest percentage of moderately fed fishes was recorded during March (69.23%). The observed monthly mean VI value of *P. anea* was zero in all months except a major peaks in January (77.19%) and February (54.90%) and minor peaks during September, 9.8% and October (4%). The FI values varied from a minimum of 0.75 during March to maximum of 3.06 in July followed by gradual decline to 1.73 in October and an increase thereafter up to February. The diet analysis based on IRI revealed that *P. anea* preferred 92.58% of teleost fish as chief diet in all months followed by shrimps 5%, crab 1.56% and scales 0.86%. The most frequent prey items among teleost fishes in the diet of *P. anae* were *Bregmaceros mcclellandi*, *Stolephorus* sp., *Sardinella longiceps*, *Sardinella* sp., Silverbellies, *Sillago* sp., *Terapon* sp. No ontological as well as sex wise variation observed in the diet preference of both sciaenids under study.

# Gastropod fishery of Andhra Pradesh, India

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The phylum Mollusca has a tremendous impact on Indian tradition and economy since the dawn of human civilization. Shell handicraft is an age-old industry of our country. Molluscs have assumed greater significance in our industrial, technological and aesthetic aspects of life. Gastropod constitutes a large and highly diversified class within the phylum Mollusca and nearly 3271 species of molluscs have been reported all along the Indian coast including about 1900 species of gastropods. Apart from forming as a minor food component among the fisherfolks, the shells are used as a raw material for many calcium carbonate based industries, handicraft and shell craft industry. Several cottage industries in South India produce curios and other decorative objects by making use of the gastropod shells. The polished whole shells and numerous types of shell crafts items are in high demand across the globe.

The estimated fishery of marine gastropods of Andhra Pradesh stands at 568 t. Chepala Kancheru a fishing village in Vizianagaram district and the Chollangi centre of Kakinada Bay are the two main gastropod landing centres of Andhra Pradesh. The Fishermen of 'Kancheru' and 'Chollangi' are traditional fishermen; they use both artisanal and small motorised crafts for fishing. Nearly 50% of boats are fibre boats and others are plank built canoe. The gillnets and dragnets are used for fishing operation other than handpicking of gastropods. Based on mesh size 9 types of gillnets are being used by the fishermen especially at Kancheru on different seasons. They are *'Naram Vala, Chandua Vala, Pethulu Vala, Joga Vala, Siraga Vala, Attukula Vala, Kathiruvala Vala, Pulusa Vala* and *Disco Vala'*. In the gill nets, gastropods forms a sizeable quantum as a by-catch along with the crabs mainly in the bottom set gillnets. During the observation period 2012 to 2018, the gastropod fishery showed a fluctuating trend. The gastropod catch drastically reduced due to the lack of demand of button shells during 2017. The main species contributing to the gastropod fishery were *Pirenella sp.* (40%), *Murex sp.* (15%), *Volegalea cochlidium* (11%), *Telescopium telescopium* (13%), *Umbonium vestiarium* (8%) and others (13%). More landings were observed during Oct-Jan month *i.e.* when the cold current begins. On these season a single fisherman sells about 2-3 bags (30-50 Kg per bag) of shell every two months and during off seasons they sold about 2 bags in 3-4 months to the agents.

The price of the shell is Rs. 2-10/ Kg for lime industry and for the ornamental purpose the shells cost ranged from Rs. 1-50 based on the species, condition of the shell and size of the shell. The shells caught with operculum gets more price than the dead shells due to the demand of gastropod operculum for other purpose.

# Status, trends and challenges in urban Small-Scale Fisheries (SSF): observations from mumbai, india

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The dependence of human on fishery resources is continuously increasing to meet the food demand, nutritional security and livelihood. Most of the worlds fishing population is dependent on small-scale fisheries (SSF). Worldwide, SSF is the primary occupation of the millions of fishers who are directly engaged in the fishing related activities. The small-scale fisheries are dynamic and diverse in nature, uses small vessels and conducts near shore fishing. Most of the small-scale fisheries are often unrecognized or unmonitored and are challenged by multiple natural and anthropogenic threats.

In India, most of the studies on SSF have focused on socio-economic aspects and there is an urgent need to characterize the fishery and allied activities of partialised SSF community, understand how the human activities, policies and climate are affecting the livelihood of small scale fishers especially in the urban areas of India. Mumbai, the capital of Maharashtra is a million-plus populated coastal city where the urbanization is rapid. In some parts of the city, there are few coastal fishing hamlets which still survive on SSF, competing all odds for resources and space in the sea and land. In this study, we characterise the urban small-scale fisheries of Mumbai, based on the obseravations at Cuffe Parade and Versova. Adverse fishing practices and variations are observed across seasons. The percentage of small scale fishers in the total fishers are unusually high at Cuffe Parade (90%) than Versova (<20%). The areas of fishing gears operation by small scale fishers of Versova are extended up to Worli within 10 -14 nm. Whereas, the fishers of Cuffe Parade are fishing up to Alibaug. The commonly used fishing gear is gillnet in both the sites. Depending upon the season and target species, different variations of gears and crafts are used for fishing. There is targeted fishery of *Escualosa thoracata* using the locally called Bhiljijal of mesh sizes 15- 22 mm. A targeted fishery also exists for lobster, *Panulirus polyphagus*, spadenose shark *Scoliodon laticaudus*, Pomfrets, Polynemids and Mysids using Sewendijal (mesh size 80-100 mm), Musijal (mesh size 120-180 mm), Sargajali (114-130mm), Waghrajal and bag nets respectively. The catches are sold in the nearby retail markets. Vulnerability perceptions of the fishers were ranked and identified as depletion of resources, overcrowding of vessels in the sea, urbanization in near shore areas, weather and pollution as major ones. This study characterises the urban small scale fisheries of Mumbai, and provides a baseline data for researchers and policy makers for the better management of the fishery and securing the livelihood of urban small scale fishers.

# Studies on Halfbeaks (Family: Hemiramphidae) along the Tuticorin coast, Gulf of Mannar region of India

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Halfbeaks (family Hemiramphidae) are one of the commercially important pelagic fishery resources exploited globally due to its excellent taste. They are distributed in brackish, marine and freshwater of tropical and temperate regions. These pelagic fishes inhabited at surface water are omnivores in feeding habit, mostly preying upon planktons. The family Hemiramphidae is having 62 valid species comprise of eight genera, namely *Arrhamphus*, *Chriodorus*, *Euleptorhamphus*, *Hemiramphus*, *Hyporhamphus*, *Melapedalion*, *Oxyporhamphus* and *Rhynchorhamphus*. About 16 species under 5 genera of the family have been recorded from Indian waters. The availability of halfbeaks was studied along the Tuticorin coast for one year. Halfbeaks were collected using *muralnet* (a type of Gillnet) from depths of up to about 10 meters. Eight species of Halfbeaks were recorded from Tuticorin coast and of this 4 belongs to the genus *Hemiramphus*: *Hemiramphus far*, *Hemiramphus archipelagicus*, *Hemiramphus lutkei and Hemiramphus marginatus*. Two from the genus *Hyporhamphus*: *Hyporhamphus dussumieri* and *Hyporhamphus quoyi*. One from *Euleptorhamphus: Euleptorhamphus viridis* and one from *Rhynchorhamphus: Rhynchorhamphus malabaricus. Hemiramphus far* dominated the catch followed by *Hemiramphus lutkei*. In addition to details on the availability of the species, pictorial and morphometric characters are also presented.

# Age and growth studies in the Indian oil sardine, *Sardinella longiceps* using otolith, a tool to understand environmental influence on the species

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Indian oil sardine *Sardinella longiceps* is the most dominant and commercially important pelagic fish resource in the Indo- Pacific region. It is widely distributed along the coast of India mainly south - west region. Age and growth estimates of species is the most is important pre-requisite for fish stock assessment to decide upon fishery management strategies for sustainability. Traditionally, age and growths were estimated from length frequency data of species in the catch. These estimates by researchers, however varied widely. Estimation of age based on hard part inscription is the most reliable and accurate technique. Age of Indian oil sardine was determined by interpreting the inscriptions on the sagittal otoliths of wild caught fishes and that grown in open sea cages. The inscriptions on otoliths of farmed fishes were confirmed as daily increments representing one day growth. Von Bertalanffy growth model was fitted with the length at age data developed from otolith ageing for pooled population and both sexes separately. The growth parameters obtained were compared with the estimates from length frequency analysis. The result indicated that oil sardines grow very fast during early phase of their life. It was observed that the growth rate of the species vary with the ENSO Phase with growth retardation during El Nino and normal growth during La Nina phase. The otolith based age data is further useful for tracing confirming the spawning time of the fish very precisely.

# Assessment of ecological impacts of tuna fisheries of Lakshadweep, the archipelagic territory of India situated in the central Indian Ocean and ways of improvement

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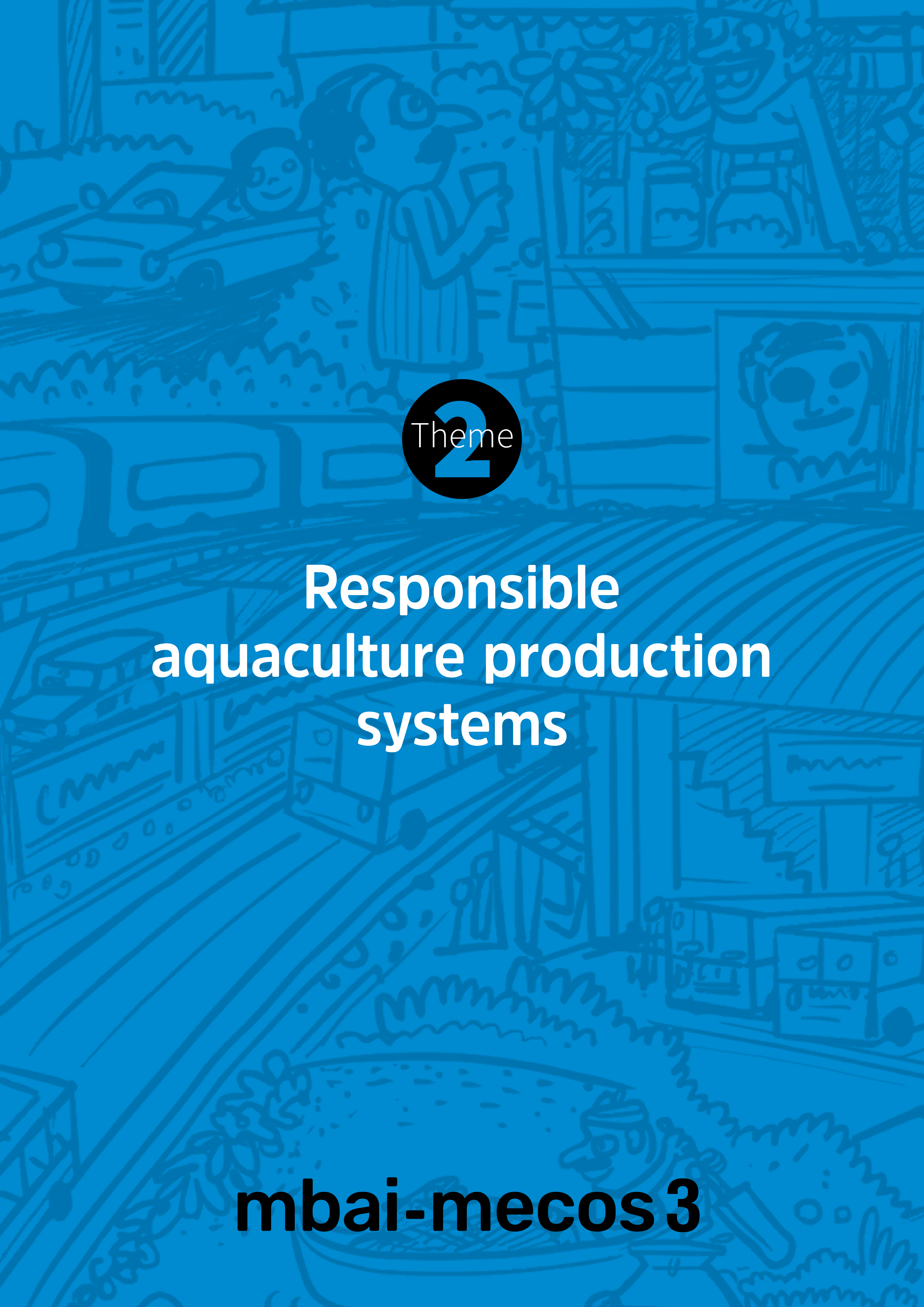
Tuna fishery of Lakshadweep, a small scale fisheries employing only hook and line methods like pole and line, hand line and troll line is *prima facie* one among the few sustainable tuna fisheries globally. Skipjack pole and line fishery of the islands is already a fishery improvement project (FIP) and is marching towards being a Marine Stewardship Council (MSC) certified fishery. However, scientific information on ecological impacts of the fishery, especially its impact on sensitive marine organisms is wanting. Skipjack pole and line and yellowfin handline fishery of the islands were studied during 2017 to 2019 basing two major fishing islands, Agatti and Kavaratti through onboard observation. Ecological impacts in the form of incidental catch of non-target resources including sensitive organisms in tuna fisheries as well as the associated livebait fishery; and physical impacts of bait fishing on the reef system were quantified. The fishery though had very minimal impacts with no incidence of sensitive species caught and total bycatch including discards at less than 0.5%, non-target resources, especially juveniles in FAD aided fishing, physical damage to the coral reef in the bait fishing operations and excessive use of baits are few concerns to be addressed. The study recommends continuous monitoring of the fishery and to bring in management interventions to mitigate impacts of bait fishing through science based management



Theme 2

# Responsible aquaculture production systems

mbai-mecos 3

# Exploring the concept of Ecosystem Approach in Brackishwater Aquaculture

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## Fisheries & Aquaculture

Capture fisheries had been the source of fish by contributing about 90% of fish consumption, where the production increased almost 4 fold during the last 50 years, while the human population and seafood consumption also doubled during this period. Racing to meet the increasing demand for seafood, the exploitation rate is faster than the rate of reproducing, resulting in an unsustainable scenario in fish catch, creating a stagnation in wild catch for the last many years. This necessitated the farming of fish in water or aquaculture to meet the increasing gap in demand. Asian aquaculture including Indian aquaculture is registering continuous growth since 2000. Aquaculture production crossed 100 million tonnes mark in 2016, becoming the major source of fish for human consumption by taking over the capture fisheries, providing more than 50% of the fish for the people in the Asian region. Aquaculture is the fastest-growing food-producing sector across the world, the produce with ready market demand providing with appreciable profits, also generating employment, altogether driving the growth of the sector.

## Potential of Brackishwater aquaculture and shrimp farming

India with vast aquatic resources across the country, different systems such as freshwater, brackishwater and marine, is available for aquaculture. Pressure on freshwater resources due to multi-user demands and climate change-related impacts constraints the expansion of freshwater aquaculture, where the production entirely used in domestic consumption. Farming in sea or mariculture is only in its experimental stage, due to the infrastructural challenges, and lack of policy gaps especially in the leasing framework. Whereas brackish waters, otherwise considered as a zero-economic resource (not used in agriculture, drinking or construction), huge resource is available in the country. Coastal aquaculture mostly practiced in brackish water areas in which the salinity is appreciable but not to a constant high level. It is usually characterized by daily and seasonal fluctuations in salinity (0.5 to 30 ppt), due to freshwater and full-strength marine water influxes. India with a coastline of 8017 km, the coastal zones have nine states, 4 union territories and 65 coastal districts and two islands. It has 97 major estuaries with 3.5 million ha of backwaters, 43,230 km$^2$ of wetlands and mangroves, and an estimated 171 million population including 4 million fishermen. With these abundant brackish waters, the scope for brackishwater aquaculture (BWA) in India is enormous.

Shrimp farming is the face of Indian BWA, where the farmed shrimp has a ready farm gate price, due to the sustainable demand of shrimp for export market. Owing to the high export market demand from overseas, the growth of brackishwater shrimp aquaculture in India has been spectacular, and the production of farmed shrimp in India has risen from about 20 mt in 1970 to 7,00,000 mt in 2018. Being the largest exporter of shrimps to the world market, the foreign exchange earnings has touched 5 billion US$ in 2017-18, and posed as the economic engine of Indian aquaculture sector.

## Need of Ecosystem Approach to Aquaculture (EAA)

Growth trajectories of the shrimp farming sector have also brought out sustainability challenges, in the form of emerging diseases, slow growth issues, spiraling cost of production and reducing the profitability, raising questions on the environmental and social compatibilities. Very often unregulated development and unscientific farming practices, non-adherence to good management practices (GMP), etc lead to catastrophic crop failures negatively affecting the growth of the sector, the collapse of tiger shrimp farming in India in the nineties is an example. The successful vannamei shrimp farming sector in India also started showing production issues with slow growth and diseases, affecting the profitability of farming. In order to provide sustainability in the production of farmed shrimp and to keep the momentum in growth, the time is up to look up to the evolving concept of ecosystem-based approach in the development of BWA, with a focus on shrimp farming.

After the Ecosystem Approach to Aquaculture (EAA) was discussed and laid out by FAO in the Code of Conduct for Responsible Fisheries (CCRF) in 1995, in 2010 FAO has brought out a detailed guidelines, to move the aquaculture development towards a sustainable model. The concept of EAA envisages a positive balance between ecological well-being and human well-being, through responsible governance. World over, whether in the capture fisheries or aquafarming, maintenance of ecosystem balance to keep the environmental and social health is increasingly discussed and the need for an ecosystem-based aquaculture for the longterm sustainability has been understood. Considering the developmental opportunities and emerging issues, the Indian shrimp farming sector also needs to consider the EAA approach, for a sustainable future.

An inclusive approach, taking into consideration of ecosystem health with its characteristics (biotic and abiotic factors, carrying capacity, boundaries, etc), stakeholder interests, operational objectives, social factors, and governance perspectives, can take the conventional approach in brackishwater farming towards an ecosystem-based sustainable farming. Further, a resource map reflecting the nature of the water resource needs to be developed and made available, using modern technologies such as geospatial mapping, supported by ground-level surveys with parameters such water depth, tide, salinity, productivity and carrying capacity. At CIBA a brackishwater resource mapping has been initiated with the support of state governments (Tamilnadu and Maharashtra). Mapping of the land and water use in nearby areas also would be useful.

## Ecosystem approach to Brackishwater Aquaculture (EABA), India

As a first step in this direction, India has the Coastal Aquaculture Authority Act (2005), where brackish water aquaculture is regulated through Coastal Aquaculture authority, under the Ministry of Fisheries, Animal husbandry & Dairying, Govt. of India. The upcoming National Mariculture Policy and National Inland Fisheries and Aquaculture policy propose the need for EAA concepts in the aqua farming. To a certain extent, the CAA addresses the management of ecosystem functions, keeping a balance on the interest of society and other relevant stakeholders, though there exists scope for larger improvement and refinement, considering field experiences. However the greatest challenge is in taking the concept of EABA to the farmers, where the Central and state govt agencies, academic and fisheries research institutions engaged in the development of aquaculture need to take the lead in taking the message to the farmers, small, medium and large scale, and also the NGOs. On the course, development of a masterplan for brackishwater aquaculture, suitable for each area, for sustainable, environment-friendly and socially acceptable farming, harmonizing the concept of ecosystem approach in aquaculture, is a requirement. A longterm policy and roadmap with a continuous monitoring system on the basis of stakeholder consultation, planning, decision making, and implementation, can serve as the drivers of the ecosystem approach to Brackishwater Aquaculture (EABA).

# Application of Recirculation Aquaculture System (RAS) Technology in Marine Finfish Breeding

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Recirculation Aquaculture Systems (RAS) are facilities in which aquatic organisms are cultured in water which is serially reconditioned and reused. They are tank-based systems in which fish can be grown under controlled environmental conditions. The technology is based on the use of mechanical and biological filters and the method can in principle be used for any species grown in aquaculture such as fish, shrimps etc. From the outlet of the fish tanks the water flows to a mechanical filter and further on to a biological filter before it is aerated and stripped off carbon dioxide and returned to the fish tanks. Several other facilities can be added, such as oxygenation with pure oxygen, ultraviolet light or ozone disinfection, automatic pH regulation, heat exchanging, denitrification, protein skimming etc. depending on the exact requirements. This technology conserves water, permits high density culture in locations where space and water are limiting, minimises volume of effluents, allows increased control over the culture environment, improved biosecurity and environmental sustainability. The major applications of the technology are in broodstock maturation, larval rearing, nursery, nutrition and health research, short term holding systems, ornamental and display tanks and high density grow out for finfish.

At a global level, in recent years a rapid growth in marine finfish culture is noted which has shown an average annual growth rate of 9.3% from 1990 onwards (around 6 million tonnes - 22.7% of farmed seafood production). This has been necessitated by the dwindling catch of high value wild caught marine finfish due mainly to overexploitation of these resources and the increasing demand for seafood. The development of breeding and seed production techniques that made possible a reliable supply of good quality hatchery produced seeds of many suitable high value marine finfishes has led to the expansion of cage and pond farming of marine finfish. In the Indian context also, the exploited marine fish production has reached the maximum sustainable levels for many resources and cage and pond farming of marine finfish is the only option for meeting the additional requirement of marine fish in the years to come. The most vital prerequisite for the development of sea cage farming is the technology for seed production and the reliable supply of good quality hatchery produced seeds of suitable high value marine finfishes. The technologies for breeding and seed production of six species high value marine finfish *viz.* the Asian seabass (*Lates calcarifer*), the cobia (*Rachycentron canadum*), silver pompano (*Trachinotus blochii*), the Indian pompano *T. mookalee,* the orange spotted grouper *Epinephelus coioides* and the pink ear emperor *Lethrinus lentjan* were developed in the country in the recent past and the immediate way forward is the commercial level production to meet the seed requirements of the fish farmers. In this context, the RAS technology can play a vital role.

The application of the RAS technology is very effective in marine finfish breeding and seed production which involves the broodstock development, larviculture and nursery rearing. The development of broodstock is a time consuming and expensive process. The broodstock development is very risky in simple onshore tank facilities with water exchange or flow through methods. The chances of ammonia poisoning and contracting of diseases such as Amiloodiniosis were found to be the major issues met with the attempts made to develop broodstock in such conditions. If such a problem is encountered while the broodstock development is underway, the whole effort taken will become futile and the entire process has to be started afresh. The uncertainty associated with the survival of broodstock adversely affects the breeding programmes. Alternatively if the broodstocks are maintained in open systems like sea cages, the occurrence of algal blooms or contracting of diseases or loss of cages due to adverse weather conditions are threats to the broodfishes. Hence it is evident that unless broodstock development is done in onshore facilities ensuring best water quality through filtration, sustainable broodstock development and maintenance cannot be done. In addition, if the broodstock is not maintained in biosecure conditions disease problems can crop up which can hamper the breeding programmes. Moreover, controlled breeding is needed to ensure seed availability as and when needed. It cannot be achieved in open systems such as cages. In this context the development of an onshore Recirculation Aquaculture System is the best option not only for the sustainable development and maintenance of broodstocks but also for controlled breeding by the manipulation of photoperiod and water temperature. In short, if the broodstock can be maintained in onshore recirculation facilities the loss of broodstock can be minimised and controlled breeding by manipulating the photothermal regimes can be achieved all through the year.

As a pioneering venture, a Recirculation system was installed at Mandapam Regional Centre of Central Marine Fisheries Research Institute (MRC of CMFRI) for the broodstock development and controlled spawning of cobia. The chief components of the system were the main circular FRP tank of 60 $m^3$ capacity, drum filter for solid removal, biofiltration unit with required capacity and flow rate, protein skimmer (with rinse system and automatic regulation) UV disinfection unit, egg collector, heating unit to increase water temperature and automated water quality monitoring and logging system. The system was effectively used for the successful broodstock development and breeding of cobia (*Rachycentron canadum*) at the MRC of CMFRI. Initially spawning of cobia was achieved in the RAS by successful development of broodstock - one female and two male brooders and they were successfully induced to spawn. The total number of eggs spawned were 2.40 million and the fertilization percentage was 86.1. The temperature range was 27.5 - 29°C. In addition, the first successful controlled spawning by thermal regulation was also achieved in the system. Subsequently very cost effective recircilation systems for broodstock development were designed and developed at Mandapam, Karwar, Visakhapatnam and Vizhinjam centres of CMFRI. The system was effectively employed in the broodstock development of Indian pompano (*Trachinotus mookalee* ) and Orange spotted grouper (*Epinephelus coioides*) at

Collection of cobia eggs from RAS at Mandapam.

Visakhapatnam Regional Centre of CMFRI. At Vizhinjam Research Centre of CMFRI successful broodstock development and breeding of the pink ear emperor *Lethrinus lentjan* was done in the indigenously developed RAS facility.

Seed scarcity is the major constraint for the expansion of marine finfish farming. The newly established hatcheries will not be able to produce the broodstocks of the fishes immediately. In this context, establishment of onshore broodstock centres with recirculation systems and photothermal conditioning facilities will be a step forward in the production and supply of fertilised eggs or yolk sac larvae of required species to hatcheries as and when needed. The larvae and fingerlings are also very sensitive to water quality parameters and maintaining optimal conditions in the rearing system is vital to get good survival rates. Here also appropriate designs of RAS can be developed which will enhance the survival of larvae and fingerlings. The same is being effectively practised internationally for larviculture and nursery rearing of many species. The hatcheries established at the different states can obtain the fertilized eggs or yolk sac larvae from broodbanks and do the larviculture and nursery rearing in appropriate facilities with RAS and supply the ready to stock fingerlings to required cage/pond farmers. It is felt that the application of RAS technology in marine finfish breeding and seed production can pave the way for the successful commercial level production of healthy fish seed of the different species to meet the requirements for the fish farmers leading to substantial farmed marine finfish production in the country in the near future.

# Ecofriendly and energy efficient aquaculture systems in Asia

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Aquaculture is currently the world's fastest-growing food production sector, and the most diverse farming system in terms of the number of species (both animals and plants) farmed, the farming methods used, and the different environments in which the animals are farmed. Profit-driven commercial aquaculture has been rapidly expanding throughout South and Southeast Asia since the late 1970s, with increasing intensities and scales of operation. A rapidly growing demand for seafood in both domestic and export markets, associated with a booming human population and the diminishing capture fisheries stocks, appear to be the primary drivers for intensification in global aquaculture. However, aquaculture is also impacted by several natural and anthropogenic factors including natural disasters, global climate change, and degradation of aquatic ecosystems. For aquaculture to remain sustainable, farmed species must be resilient to the impacts of a changing climate by expanding to a broader species base using resilient technologies and adopting resource-efficient and environmentally friendly culture systems.

## Global aquaculture output

The Asian region currently contributes about 89% of the world's aquaculture production. The top producers are China (61.5% of world production), India (7.1%), Indonesia (6.2%), Vietnam (4.5%), and Bangladesh (2.8%). FAO estimates the global aquaculture to have produced 110.2 million tons valued US$ 243.5 billion in 2017 (FAO, 2019). This production included 80 million tons of food fish comprising 54.1 million tons of finfish, 17.1 million tons of molluscs, 7.9 million tons of crustaceans, and 0.94 million tons of other aquatic animals (turtles, sea cucumbers, sea urchins, frogs, edible jellyfish, etc.); 30.1 million tons of aquatic plants comprising mostly seaweeds, and microalgae; and 37,900 tons of non-food aquatic products (ornamental shells and pearls).

## Environmental challenges to sustainable aquaculture

There are several challenges to sustainable aquaculture in the Asia Pacific region, with the intensive scale of operation becoming prevalent. Aquaculture facilities impact directly on water bodies by discharging their effluents that contain both organic and inorganic materials, thereby increasing their load on the environment where the effluent is released. Export-oriented aquaculture often relies on intensive farming practices of valuable species, and this has been a point of contention by environmentalists in their quest for environment-friendly food production. This is especially relevant considering the species like trout and salmon in Europe and the United States; and shrimp, tilapia and pangasius in Asia.

Aquaculture development in Asia was mostly unplanned and undirected, rather than following an interventionist strategy with a planned and intentional intervention by government or external agents. The initial drive for the rapid expansion of aquaculture came through the development of breeding technologies, either by internationally or nationally funded projects or by private/academic-sector initiatives. Traditional, environmentally benign, low input extensive or semi-intensive culture systems were not attractive to many farmers because they made only a minor contribution to their income. The farmers intensified their culture systems by increasing the stocking density and using commercial feeds with little or no intervention from the respective governments. These rapid, unplanned aquaculture intensifications in Asia have resulted in adverse social-ecological impacts such as landscape changes (deforestation and wetland conversion), salinization of aquifers, poor surface water quality, indiscriminate drug and chemical use, genetic dilution through escapees, intensive energy consumption, disease outbreaks, and boom-and-bust market failures. However, aquaculture in many parts of Asia is currently passing through a phase of transition to an era of sustainable intensification encouraged by the growing demand to produce high-quality seafood.

## Energy consumption and efficiency in aquaculture

Energy consumption constitutes only a small component in aquaculture compared to other economic activities and gives only a partial tool to assess sustainability. Energy cost of production in aquaculture indicates the efficiency of production systems and processes, ecosystem resource use efficiency, degradation of non-renewable energy resources, and how alternative sources help in sustainability. It also highlights the potential cost of future societies through environmental changes, pollution, and climate change.

There has been a faster drive to intensify production systems in Asia and elsewhere in the 1990s. In the classical system transformation from polyculture to monoculture, energy efficiency also varied among different systems. Extensive systems are traditional and were primarily destined for rural, household subsistence; semi-intensive systems are characterized by moderate intensity and inputs, while intensive systems maximize production and profits under a strictly controlled operational regime. Intensive systems that are more appropriate for high values species employing high stocking density have a greater dependence on direct (use of fossil fuel and electricity) or indirect (feeds and chemicals) energy inputs, but a lower input of labour energy.

Intensive systems are characterized by increased ecosystem dependence by relying on artificial feed (that utilizes several animal/agricultural products as feed ingredients) and substantial inputs of auxiliary energy, materials, labour, capital, and technology. Direct inputs of energy are mainly destined to hatchery production, general farm management, processing, and marketing. Hatcheries need natural collection and maintenance of broodstock and juvenile production and supply to farms. Typical aquaculture farm management includes feed production and transport; and feeding. Besides, agricultural and livestock derived products as raw materials, fishmeal and fish oil production encompassing fishing fleets

**Figure 1** Mussels integrated with shrimp grown in the same pond tested in Thailand is an efficient system for effluent management while also consuming lower energy inputs (Photo by K. R. Salin)

and reduction plants, harvesting, post-harvest handling, processing, and product transport for marketing all consume substantial investment of energy and labour cost.

Several criteria qualify energy-efficient systems in aquaculture, such as those using lesser resources, lower energy consumption, and operating on the 3-R (reduce, reuse, recycle) principle. Energy intensity of an aquaculture operation depends on the species farmed (natural trophic level of the species), dependence on artificial feed, intensity of farming operation, degree of mechanization, and environmental control needed. Farming of species that occupy a lower trophic level such as herbivorous fish, seaweeds, shellfish, and the systems that integrate complementary farming components are low energy operations with decreased direct ecosystem dependence. However, the reliance on solar energy and nutrient recirculation with repeated energy loss successively in different trophic levels are the limitations of such systems. Extensive production of seaweeds and mussels also needs additional support structures such as ropes and buoys, while extensive fish and shrimp production may also need other inputs from several agricultural byproducts. Locally prepared feeds that use trash fish or locally processed feedstuff in extensive systems may also incur more energy costs in feed production compared to industrial-level production of feed pellets that potentially offer lower FCR.

## Sustainable farming systems for Asia

The adoption of more environmentally friendly and energy-efficient systems is essential for the rapid development of aquaculture. Aquaculture can be carried out using either fed or non-fed species, with the latter having a goal to reduce resource use in the form of feed while also ensuring environmental integrity. The culture of single species (monoculture), two or more species (polyculture), and the integration of species occupying complementary trophic niches (integrated multitrophic aquaculture; IMTA) are examples of species combination as an aquaculture system practiced in Asia. In such systems, the by-products from one species are used as inputs (fertilizers, food and energy) for another such that fed aquaculture species (e.g., finfish/prawn/shrimp) are combined, in the appropriate proportions, with organic extractive aquaculture species (e.g. suspension feeders/deposit feeders/herbivorous fish) and inorganic extractive aquaculture species (e.g. seaweeds). This enables a balanced ecosystem management approach aimed at energy efficiency, environmental sustainability through bio-mitigation, economic stability through product diversification and risk reduction, and social acceptability through better management practices.


Figure 2 Rice - crayfish/prawn integration is a sustainable practice as followed in China (Photo by K. R. Salin)

# Recent development of marine fish farming in Vietnam

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Vietnam is a coastal country with great natural potential for development of marine aquaculture. The coastal line of 3260 km, the economical zone of more than 1 million km$^2$, and abundance of islands and bays create suitable water surface for marine aquaculture, approximate of 500.000 ha. In addition, Vietnam has rich and diversified natural resource with many economical aquatic species that can be farmed as marine fish, crustacea, mollusc and seaweed. However, marine fish farming in Vietnam has not developed compatibly to its potential. In general, fish farming mainly locates near shore and sheltered areas with small scale production (family scale), using trash fish as main feed source. Fish farming in near shore is facing with pollution, conflicting with other use of water resources such as tourism, transportation and resource conservation. Nevertheless, with application of research results and advanced technology, marine fish farming sector has recently obtained remarkable achievements in seed production, modernizing farming by using large scale plastic (HDPE) cages in more open area. Production of marine fish farming in Vietnam has increased from 15.000 tons in 2010 to about 50.000 tons in 2018.

Before 2010, marine fish fingerlings were totally relied on wild catch or import from neighbor country. With application of breeding technology, fingerlings of more than 20 marine fish species are now successfully produced, of which key cultured species are grouper (*Epinephelus spp*), cobia (*Rachycentron canadum*), pompano (*Trachinotus spp.*), sea bass (*Lates calcarifer*), red drum (*Sciaenop ocellatus*). Artificial seed accounts for 80-90 % demand of marine fish farming. This achievement was attributed to i) better broodstock management, which includes collection of broodfishes from the wild and adapts to culture condition, broodstock conditioning and artificial breeding techniques using either hormonal or environmental control, ii) development of live feed culture and enrichment techniques, and iii) development of intensive and semi-intensive fish larval rearing techniques. In addition, a prolonged ministerial program on aquatic gene conversation also helps exploring a number of wild fish species to be potential cultured species. The introduction of large scale HDPE cages which can be locally produced in Vietnam with half price of import has also effectively contributed to modernizing marine cage farming in Vietnam. Large scale marine fish farming has been operated by several foreign investment companies as such Marine Farm as, Australis and domestic companies. The cage volume is typically about 3000 m$^3$ each. Formulated feed is used in large scale fish farming. Annual production of marine fish ranges from 200 tons to 5000 tons/farm/year. Markets for marine farm fish products are much wider than before, not restricted to only live fish export to China but also to other international market such as America, Australia, Europe, Middle East. Marine fish farming using HDPE cages has a number of advantages such as better tolerant to bad weather, operating in more opened area, thus improving fish health and reducing risk of environmental pollution, and producing large quantity of fish with consistent quality required by customers.

However, marine fish farming in Vietnam is facing several challenges for sustainable development. Disease outbreak occurs quite often in small scale farms and causes great loss to farmers. Vietnam is one of five most vulnerable countries in the world to the impact of climate change with average of 8-10 storms every year. This requires a better master plan for farming area and stronger culture facility to mitigate the risk. Market development, one of the most important driving forces for further development of marine fish farming, still lags behind its production capacity.

Marine fish farming is recently received lots of attention from Vietnamese government. Production of farmed marine fish is aimed at 600.000 tons by 2030. Industrial farming scale will be main production sector to achieve the production target. Modernizing marine aquaculture is a crucial element for this movement. This includes development of vaccine for key cultured fish species, restructuring farming scale and area, increase mechanizing and automation, development of linkage among production chains and market for marine farmed fish.

# Indigenous Micro Feeds for Indian Aquaculture and Aquariculture: Challenges and Opportunities

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The first feed and early nutrition for larval and post-larval stages of shrimp and fish is highly challenging and continually evolving to meet the set of challenges from the environment, species requirement and the market. Currently, there is a high degree of dependence on live or fresh feeds in early feeding of shrimp and fish larvae. Use of live and fresh feeds have long been identified as a key risk factor for introducing pathogens and yet reduced dependence on all live feeds is possible due to the recent improvements in our understanding of larval nutrition (i.e. high dietary requirement for highly unsaturated fatty acids, larval digestive physiology, use of highly digestible dietary feed ingredients, larval feeding behaviour etc.) The availability of advanced larval feed manufacturing techniques have stimulated renewed interest in the development of artificial larval diets to replace live food organisms during the hatchery cycle. Rapid progress has been made in the development of inert micro diets for fish and shrimp and the types of diets used for this purpose are wet suspension diets, dry micro particulate, micro bound, microencapsulated and flake diets.

## Micro feeds production

Micro feeds are characterized by their sizes ranging from 50 microns to 900 microns and prepared in a form which is most suitable for the larvae of fish and shrimp to consume it and could able to retain the nutrients with suitable buoyancy for the species concerned. These are prepared as sinking, floating and slow sinking feeds of required particle size (50- 900 microns) are produced for a highly specialized market. These are presently produced as

1. Micro-particulated feeds-Production of large pellets (1 to 1.2 mm) and crumbling
2. Direct extrusion of small diameter feeds of 500 to 900 micron
3. Micro-extruded and marumerized
4. Spray dried (50- 200 micron)
5. Micro-coated and Micro-encapsulated

## Micro particulate dry diets

These diets are prepared in dry powder form. The particle size of the diets varies from 50 to 500 microns. A variety of ingredients with different functional and nutrient properties are used for formulating the larval diets. The selected quality ingredients are arranged in the form of a balanced feed formula. After finely grinding the individual ingredients they are mixed according to the formula. A suitable binder is also included for making the diet stable in water. The diet is prepared as pellets or cubes or flakes and dried at low temperature as for as possible. The dry diet is then reground and sieved to obtain the desired particle size. These micro particulate dry diets are used for feeding larvae. Separate micro particulate diets were developed for fish and shrimp larvae. In general, larval diets are formulated to contain more of natural raw materials such as premium fish meal, fish protein hydrolysate, fish oil, prawn head powder, cereal flours and feed additives. Starch present in cereal flours is mainly intended as a natural binder by the gelatinisation during cooking and good water stability of the feed.

## Direct extrusion of small diameter feeds of 500 to 900 micron

Microfeeds in the sizes of 500 to 900 micron are directly extruder in a specialized micro extruder and the feeds of floating, slow sinking and sinking can be produced. These require special machinery for grinding, mixing, preconditioning, cooking, extrusion and post pelletizing. Moreover, all the processing parameters such as moisture, starch level, fat content of the formula, ingredients combinations, temperature of cooking, pressure in the extruder barrel, etc. needs to be optimized for each and every formula.

## Micro extruded marumerized (MeM) diets

The production of MeM diets involves the technology of cold micro-extrusion and marumerization, and can ensure high water stability of soluble and insoluble nutrients in the feed while avoiding the use of chemical binders. A uniformly mixed and fine ground formulation is passed through a low shear and low-temperature extrusion process where it is conditioned with steam, water and other possible liquid additives and compressed through a special dome die to form micro extruded strands. These strands, when delivered into a spheronizer spins in a cyclonic motion, the strands will be broken to small pieces and made into spheroids in few seconds. The sizes and shapes the pellets will be determined initial diameter of the extruded strand and configuration of the spinning disc in the Marumurizer. Feeds in the size range of 0.3 to 1.2 mm can be produced. Low processing temperature minimizes nutrient damage in this way of processing. Here the advantage is cold micro-extrusion avoids high temperature during the production process and keeps high vitamin levels and digestibility of nutrients and favors production of medicated feeds and utilization of other temperature sensitive ingredients.

## Spray dried diets

The finely powdered feed mix is mixed with required quantity of water and then spray dried using a spray drier. The spray dried particle sizes are controlled by varying the atomization, flow rate and temperature. Microencapsulation is also possible through spray drying by coating the spray dried powder through proper binders. These are specially used to prepare feed particle in the size range of 50 to 200 micron. The main

Cold extrusion cum Spheronization (Micro extruded marumerized feed production) disadvantage of this method is it is not amenable for all the materials and certain heat sensitive nutrients are lost during this process.

## Micro coated and Microencapsulated diets

Microcoated diets are obtained by coating the micro particulate diet with suitable materials. This is done mainly to prevent leaching of nutrients from diet particles and to improve the nutritive value of the diet. Cholesterol, lecithin, zein and nylon protein are used as coating materials.

Shrimp larval diets are prepared as capsules in order to prevent leaching of important nutrients into water before entering the stomach of larvae. Since these capsules are minute in size (10 to 200 microns), they are known as microcapsules. Different types of diets such as liquids, semisolid and dry powders can be encapsulated. The material used for making the capsule is called wall and the inner portion (diet) is called the core material. The principle involved in encapsulation is the interfacial polymerization. A number of materials are used as wall coating. These are gelatin gum acacia, egg albumin, glycopeptides, chitosan and nylon protein

## Relevance of micro feeds for shrimp larvae in the Indian context

The majority of the hatchery feeds, mainly larval feeds for shrimp and fishes in Indian market are imported ones. To our knowledge, there is no known larval feed manufacturing firm that produces larval feeds on a commercial scale. At present, the larval feeds from multinationals such as Inve, Skretting, Zeigler, SIS, Biomar, Tierarzt and Nutreco are used. The cost of larval feeds ranges from INR 2000 to 7000 per kilogram. As per the industry estimate about 700 to 1000 tons of larval feeds are used per annum and the feed cost alone comes to about 300-400 crores per annum. CIBA has done extensive research in larval feed and has developed the larval feed for shrimp, CIBA Shrimp larvi$^{Plus}$ This feed has been tested in the commercial vannamei hatcheries in collaboration with a private partner and the results showed on par performance with imported feeds. The main advantage of the Shrimp larvi$^{Plus}$ is the cost-effectiveness and this feed is in the process of commercialisation. There is good scope for indigenous larval feeds manufacturing in India.

## Feeds for aquariculture

Aquarium keeping hobby is on the rise across the world, and the ornamental aquarium industry is today a multi-billion-dollar industry with an estimated value of 15 billion US dollars involving trade in over 5000 species of fishes. India is blessed with a rich natural biodiversity of fish species including over 400 ornamental fish species. In addition to international trade, experts estimated that Indian domestic aquarium market will grow from ₹300 crores to ₹1200 crores. Feed alone contributes about 30% of the cost of this industry and there is a huge scope for ornamental feeds in India.

Nutrients essential to ornamental fish are the same as those required by most other food fishes like the exclusive requirement of proteins (amino acids), lipids (fats, oils, fatty acids), carbohydrates (sugars, starch), vitamins and minerals. In addition, pigments (carotenoids) are commonly added to the diet of ornamental "aquarium" fishes to enhance their skin coloration and the primary objective of the feed is to maintain the skin colour and health of the ornamental fish rather than the growth per se. Hence while formulating the feed for aquarium fishes the critical nutrients required for proper colouration and better health are to be take care in addition to the maintenance requirement of the fish. The synthetic pigment, astaxanthin, canthaxanthin are the most commonly used additive (100-400 mg/kg). The blue-green algae, *Spirulina*, dried shrimp meal, crab shell meal, shrimp and palm oils, and extracts from marigold, red peppers and Phaffia yeast are excellent natural sources for pigmentation. About 80% of the ornamental fishes in display aquariums are fed with exclusively prepared foods that most commonly are produced in the form of flake, pellet or tablet. The larval and fry stages of the fish are fed with micro feeds in the form of microparticulated/micro extruded/ micro encapsulated/ flakes/ extruded spheres and pellets.

CIBA has done extensive research on the development of feeds for ornamental fishes and developed and branded it as Kalor fish *Plus*, a versatile feed for all the aquarium fishes. This feed has been extensively tested and the technology has been commercialised on a nonexclusive basis. Though there are some Indian companies recently ventured into aquarium feed manufacturing, majority of the market share is still with the imported feeds. There is a huge demand for quality ornamental feeds to improve larval survival in the hatchery and to improve the health and colour in the aquarium is growing. However, imported feeds are very expensive and there is no assurance on the quality of the feeds. ICAR-CIBA realized the urgent need for an indigenous micro feed technology for especially for ornamental feeds and accomplished it. This will be of great use for people involved in ornamental aquarium business, aquarium hobbyists and breeders.

## Conclusion

The Indian feed industry has rapidly evolved over the years catering to the needs of fast-growing aquaculture during the last five years in shrimp and carp grow-out sector. However, the micro feeds sector, especially for larval shrimp and ornamental fish continue to depend on imported feeds. Availability of the indigenous technology coupled with the establishment of the state of the art facilities for micro feed production, novel, scientific and innovative approaches in feed formulation, and improved methods of feed management would cater to the rapidly growing hatchery feed sector also. The availability of cost-effective and quality feeds to aquarium breeders and hobbyists will also pave the way for the continued growth of the ornamental feed industry. Though the production of micro feeds for hatchery and aquarium feeds are challenging to process, they have got an enormous scope in India as an enterprising business in the years to come. Also these recent developments in larval and ornamental feeds sector will very much support the growth and contribute to the sustainability of this vibrant Indian aquafarming sector.


Indigenous cost-effective ornamental fish feed developed and branded as Kalor fish Plus has been commercialised on a nonexclusive basis

# Fish Feed Industry of India - The Past, Present and Future

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Total farmed freshwater fish production in India in 2018 is estimated at 6.24 million metric tons (MMT), which is close to two-thirds of the total fish production in the country from both capture and culture sources. The growth in the fish farming sector mainly comes from the freshwater aquaculture sector, as marine finfish culture is yet to be practiced on a large scale. Historically, the Indian freshwater fish farming was based on multi-species system. Natural fish food organisms were generated by adding organic and inorganic manure to water and the multi-species utilize this food based on the trophic system that lives in the pond. For a long time, India did not change from this type of fish farming. Nutritionally poor feed ingredients in loose form were fed to fish using feed bags or by directly broadcasting it into the ponds. The feed conversion ratios (FCR) in this type of feeding systems range from 3-4 kg of feed to 1 kg of fish production.

India did not appear on the list of Asian countries that produced formulated fish feed until 2007/08, and it was in 2008 that the first fish feed plant became functional. The feed-based farming demonstrations conducted by the U. S. Soybean Export Council since 2003 were instrumental in opening some opportunities for fish feed industry. Aligning with the introduction of scientifically formulated, extruded floating fish feeds was the regularization of farming of Pangasius (*Pangasius hypophthalmus*) in India.

The first extrusion feed mill in India was inaugurated in 2008 and thereafter there were an array of feed mills that were constructed and operated. By the end of 2013, there were 12 feed mills with an installed capacity of 1.55 MMT of feed per annum. About 683,000 MT of extruded fish feed was sold in 2013, indicating a feed mill utilization capacity of 44%. By 2018 there were 30 fish feed mills in India with a collective installed capacity of 2 MMT per annum. About 1 MT of fish feed was sold in 2018, indicating a feed mill utilization capacity of 50%.

The introduction and popularization of feed-based fish farming in India has resulted in many other advantages. The amount of organic loading that supplemental feed contributed to water bodies in the country has significantly been reduced due to introduction of formulated feeds. The feed-based system has clearly led to some recent, small developments in the species diversification efforts. Modern feed mills with good imported equipment can now produce high-protein, high-energy feeds for species like the Asia Sea Bass or Barramundi (*Lates calcarifer*), Snakeheads (largely *Channa striatus* sp.), Pompano (*Trachinotus blochii* sp.) and Cobia (*Rachycentron canadum*) and this is seen as encouragement for farming new species.

India has traditionally used only the pond-based fish farming systems and has not strongly considered other options for culture system diversification that could greatly increase fish production. Recently, a few provinces in India have taken up cage farming of freshwater fish. In fact, the limitation for the development of cage culture until 2008 was that extruded floating fish feeds were not available, but this constraint has now been overcome. In addition to the pond and cage-based systems, India can also adopt many other modern systems that can significantly increase production and at the same time conserve water, land usage, optimize inputs such as feed, power, fuel and other inputs.

Despite significant consumption of fish by Indian people (12.8% of total animal protein sources), the country still falls short on fish protein availability at 5.04 kg/ person per year, compared to world consumption at 20.5 kg per person in 2019. A few assessments made in India reveal that there are five important factors responsible for low preference for fish protein/fish consumption. India must also address a few challenges for fish farming and these will automatically lead to higher capacity utilization of feed and feed milling infrastructure. The paper discusses about 13 interventions which cover technical, biological, infrastructure and policy decisions that will help the industry in future.

India holds the second position in the world fish farmed production. There is immense scope for its development when improved systems and species are adopted; currently seen as constraints. These developments that form forerunning tactics will eventually lead to a strong feed-based farming system. A large extent of Indian aquaculture is still based on traditional farming methods. Converting them to modern farming methods will increase fish production and will also address sustainability of environment. The marine fish farming segment is hitherto untapped and establishing commercial hatchery technologies and suitable farming methods is yet another significant opportunity, given the vast marine resource the country has.

# Reproductive performance, larval growth and salinity tolerance of penaeid shrimp *Penaeus japonicus* Form II from southeast coast of India

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Kuruma shrimp also known as *Penaeus japonicus* is a popular and highly priced species in the live fish market. Recent morphological and molecular studies confirm that the native Indian stock of this species as *Penaeus japonicus* Form II. Breeding, larval rearing and farming experiments were conducted to evaluate the seed production and growth performance of this species. The broodstock was procured in batches (n=50) from Chennai, Tamil Nadu, SE coast of India. The average sizes of the female shrimps were 65.71 ± 3.45 g in weight (BW) and 18.9 ± 0.32 cm in total length (TL). The males were smaller than females and weighed 37.1 ± 3.53 g (BW) and 15.7 ± 0.43 (TL). Female brooders were divided into two treatment groups (T1- Maturing and T2- immature) and were unilaterally eyestalk ablated. No significant difference was observed in fecundity (T1-542 ± 53, T2-487 ± 19 no of eggs/g BW) and the average number of eggs (T1-32320, T2-26986) among the two treatment groups. Further, a higher percentage of hatching was observed in T1 (82.59 ± 2.49%) than in T2 (78.21 ± 3.5%) but was not statistically significant. Average larval survival at post-larvae stage 37.7 ± 2.7% and 25.52 ± 5.5% was observed in T1 and T2 respectively. The post-larvae produced were subjected to growth and salinity tolerance experiments. Growth and survival were evaluated at four different salinities (T1-5ppt, T2-10ppt, T3-15ppt, T4-25ppt). Survival and growth at all salinities expect 15ppt was not significantly different. Further, a field farming trial was conducted at Chirala, Andhra Pradesh in a 600m$^2$ lined pond provided with river sand as a substrate. The Average Weekly growth Rate (AWR) and the Average Daily growth Rate (ADR) of the species during the trial were 0.86 g/week and 0.12 g/day respectively.

# Effect of dietary protein levels on growth, survival and biochemical aspects of fish pearlspot *Etroplus suratensis* (Bloch, 1790) larvae reared in periphyton based system

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Pearlspot (*Etroplus suratensis*) is a low fecund euryhaline cichlid fish which is highly known for the complex parental care. Pearlspot is a potential fish for farming in coastal waters where the availability of quality seeds in adequate quantity is the bottleneck. Nutrition plays a critical role in the production of quality seeds of any fish. Being a fish with omnivorous feeding habit, this fish can be reared with greater survival in the presence of natural feeds such as periphyton formed in the hard substratum.

The objective of the present research was to optimize the dietary protein level in larval *E. suratensis* reared in a compact rearing system with naturally formed periphyton. Captively bred 2250 14 dph larvae (7.13±0.03 mg) were randomly stocked in nine small floating cages installed in 1000 L FPR tanks kept in outdoor with green water with pregrown periphyton at the rate of 250 larvae/cage in triplicates. Larvae were fed experimental dry larval feed (particle size 150µ) with varying crude protein levels such as 25%, 30% and 35% for 55days. Feed was offered three times daily to their satiation.

After 55 days the fry was harvested, counted and measured for final weight and length. The carcass was analyzed for biochemical composition. The result of these studies shown that the growth performances and feed utilization were significantly higher ($P<0.05$) in fishes fed 35% CP diet compared to other diets. The larvae fed 35% dietary protein obtained the highest final weight of 243 mg and 25% dietary protein was lowest as 204 mg. However, there was no significant difference in the case of survival & proximate composition of fish fry among the dietary treatments. The PER of the dietary treatments ranged between 0.686±0.01 and 0.807±0.05 and the lowest FCR 1.75±0.01 was found in 35% dietary protein.

Fig 1: *E. suratensis* fish larvae

Fig 2: Experimental setup

Fig 3: Crumbled dry feed used in experiment

Fig 4: *E. suratensis* fish fry

This study concludes that pearlspot larvae can be successfully reared with maximum survival of >70% in the absence of parental care with a dietary protein of 35% in a simply managed periphyton based compact rearing system. This method nursery rearing will be an apt model for homestead based seed production in this low fecund fish.

# Physiological response of broodstocks of Indian white shrimp, *Penaeus indicus* to diet rations and captivity

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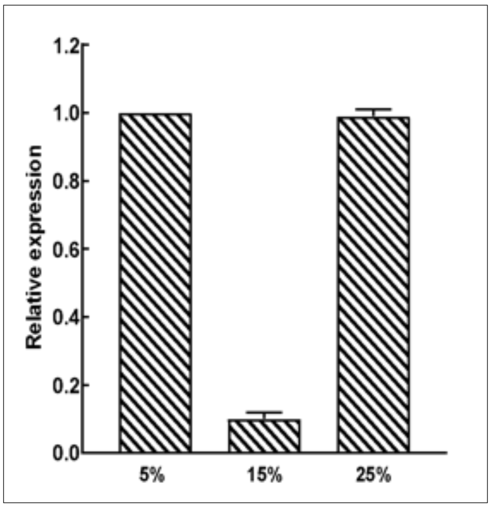
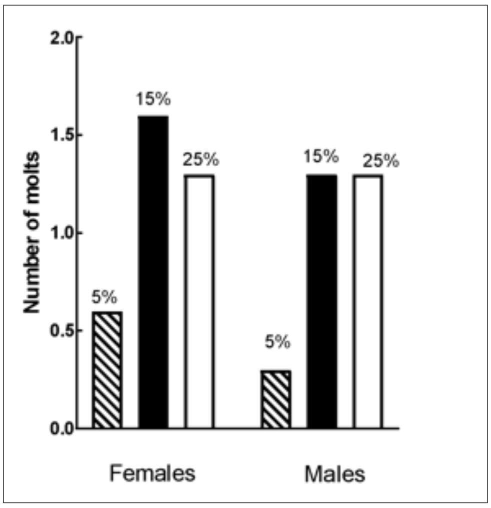
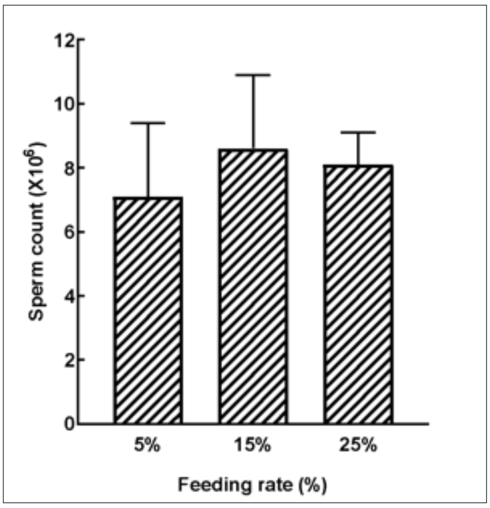
Indian white shrimp, *Penaeus indicus*, has been identified as the national priority species for the domestication and genetic improvement program, which is the crucial step for the sustainability of Indian shrimp farming sector. Understanding the effect of captivity and nutrition on physiology/biology of broodstock is pivotal for successfully management of reproduction under captive conditions. Molting or ecdysis is one of most important biological event that is intimately linked to health, growth, and reproduction of crustaceans. Gonad/vitellogenin inhibiting hormone, G/VIH, has been considered to be the most intense reproductive hormone that regulate the vitellogenesis in crustacea. In this context, therefore, we evaluated the effect of different dietary rations on molting, GIH mRNA levels, specific growth rate, and male reproductive quality under standard hatchery conditions. Wild-caught *P. indicus* broodstocks (TL-155±5 mm; body weight-32.0±3g) were reared for 45 days at stocking density (1 M: 1 F) under different feeding regimes (5%, 15% and 25% of body weight with clam/squid meat and formulated feed twice daily). The water quality characteristics were maintained based on standard operating procedure of penaeid shrimp. After 45 days experiment the molting frequency was found to be significantly higher in the group received 15% of biomass followed by the treatment received 25% of biomass. However, no significant change in the specific growth rate was found in any treatment group indicating that adult animals would not grow after molting. After the 45 days rearing GIH mRNA levels reduced to the minimum level at the treatment group where animals fed at the rate of 15% of biomass. It indicates that more than captivity nutritional




Relative expression of gonad inhibiting gene under different feeding regime




Sex-wise moulting frequency under different feeding regime level influences the reproductive hormone level, and nutritional status of the animal determines on/off mechanism of reproduction in potentially reproducing females. At the end of the experiment, contrary to the female reproduction, male reproductive quality was not found to be affected with diet or captivity, although higher sperm count and seminal characteristics were found in the group received 15% of biomass diet. The present study suggests that 15% of biomass of broodstock is optimum for the broodstock management in *P. indicus* hatchery, on the contrary to common commercial practice of providing 25% of body weight, and this study also advances our understanding of biology of G/VIH hormone.



Sperm count under different feeding regime

# Concept of box culture of mud crab *Scylla olivacea* (Herbst, 1796) and its integration with finfish *Mystus gulio* (Hamilton, 1822)

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Mud crab is one of the most valuable crustaceans in both domestic and export markets. In recent years, a box- culture method of crab grow-out has gained popularity among mud crab farmers due to the ease of observation and elimination of cannibalism. In order to assess the growth performance of mud crab (*Scylla olivacea*) in the box-culture system, a 60 days growth experiment was carried out in 27 boxes. During the study, the effects of three different feeds such as trash fish (*Coilia neglecta*) (T1), gastropod meat (*Bellamya bengalensis*) (T2) and formulated feed (T3) on growth and survival performances of individually box-cultured mud crab, *Scylla olivacea* were evaluated. The average initial size of mud crab was 58.22±5.37g, 61.33±4.21g and 63.55±4.71g in T1, T2 and T3 respectively. The growth rate of mud crab remains highest from the second week till the end of the culture in T2 treatment. There was a significant difference ($P<0.05$) in the final ABW (g) and DWG (g/d) in which molluscan meat-fed (T2) animals recorded the highest ABW of 136.22±10.43g and DWG of 1.33± 0.12 g/d. There was no significant difference ($P > 0.05$) in the SGR among the three treatments at the end of the culture. Although the growth parameters are better in the live feed, the best FCR and PER were recorded in T3 (2.52 and

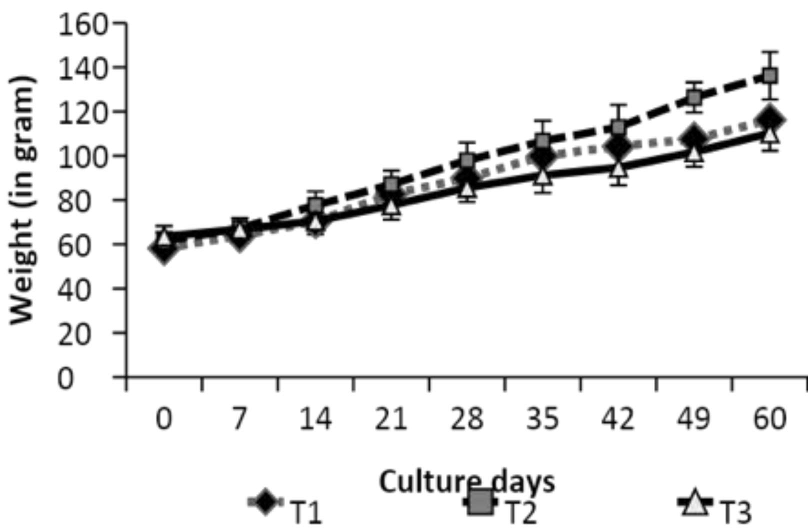


**Fig. Growth curve of *S. olivacea* fed trash fish** (T1), molluscan meat (T2) and formulated feed (T3)

Co-culture of *S. olivacea* with *M. gulio*

1.04) compared to trash fish (3.63, 1.65) and molluscan meat (3.26, 1.96). The survival of individually (box) culture of mud crab during the 60 days was 100% in all treatment. In the second experiment, the co-culture of mud crab in boxes along with *Mystus gulio* was carried out for 120 days. Mudcrab (initial weight of 48.062 g) stocked @ 1/box (60 boxes/ 100 $m^2$ area), attained 104.05 g and *M. gulio* fry (average weight: 0.133 g) stocked @ 10 nos $m^2$ attained 24.11 g at the end of culture period. Survival was recorded at 87.22 % for mud crab and 40.54% for *M. gulio*. Mudcrab culture in boxes has its advantages such as predictability, cannibalism and easy assessment of culture animals. Further, polyculture along with other compatible finfish in ponds is a sustainable farming method for optimum utilization of space and resources compared to monoculture.

# Grazing efficiency of three marine calanoid copepods on different micro algae

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Copepods are likely the most numerous metazoans on the earth. Being the pioneer feed for newly hatched fish larvae, copepods also have a significant role in the aquatic ecosystem as grazers. Since these are the most abundant primary consumers in marine ecosystem feeding on a variety of micro algae, the study on their feed preference and feeding rate have very much significance.

Laboratory feeding experiments were conducted using adult individuals of three different marine calanoid copepod species *Bestiolina similis*, *Parvocalanus crassirostris* and *Acartia southwelli* to study the grazing rate of them on seven different microalgae in a monoalgal feed trial. The algal species used for the experiment were *Chlorella marina*, *Dicreteria* sp., *Nanochloropsis oculata*, *N. salina*, *Isochrysis galbana*, *Chaetoceros calcitrans* and *Pavalova lutheri*. Twenty four hour feeding trials were carried out with hundred adult individuals of each copepod species in plastic beakers of 1 L volume filled with 500 mL mixture of dechlorinated sea water of salinity 35 ppt, pH 8.2 and micro algae in a density of $100 \times 10^{4}$ cells/mL. Triplicates were set for each algal sets and control beakers having algal cells in the same density and without any zooplanktons were kept along with the experiment beakers. Algal cell density in experiment beakers and control beakers were estimated after twenty four hours by counting using haemocytometer under compound microscope.

The experiment result indicated that *B. similis* feed more on *C. marina*, *P. crassirostris* on *N. oculata* and *A. southwelli* on *P. lutheri* in terms of algal cell number. Similarly, *B. similis* feed less on *Dicreteria* sp., *P. crassirostris* on *C. calcitrans* and *A. southwelli* on *C. marina*. The average algal cell consumption of the three copepod species indicates that *N. oculata* is the most ingested algal species and *Dicreteria* sp. the least consumed one in terms of cell number. Among the three copepods, *P. crassirostris* consume more algal cells followed by *B. similis* and *A. southwelli* being the least efficient grazer. This experiment does not reveal the actual algal preference of copepods in the natural marine ecosystem where a variety of algae are available. Laboratory feed trials on copepods carried out with multi algal species are difficult to interpret due to the varied ingestion rate of different algae. Further experiments with multi algal feed combinations are to be done in order to obtain a clear idea about the algal preferences and ingestion rate of these copepods in natural ecosystem.

# Blockchain technology for aquaculture-a viable option?

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The world today is digitally driven. Blockchain is a technology that increases trust and transparency in a system by storing all transactions in a digitalized manner. Blockchain technology has been employed in agriculture for long, and in the seafood industry, of late.

Blockchain technology is implemented for three specific reasons 1. Security - the industry and the consumers need to be absolutely sure that the fish they are purchasing is the correct fish. Producers invest heavily in sustainable farming and do not want to risk inferior products being sold as their product. 2. Market demand-Supermarket chains are demanding proof, and insist on knowing where the food is coming from. 3. Traceability - customers, and consumers demand traceability, present systems are often substandard and do not provide adequate information. Though blockchain technology is a relatively recent entrant in the field of aquaculture, there is tremendous interest being generated from the industry with respect to digital strategy, artificial intelligence, and blockchain. Blockchain and other cutting-edge technologies support the industry by making better, more effective decisions during the production cycle. Data gathered include that on the environmental impact, feed, growth and fish health helps sustainable culture. More relevant data gets gathered, leading to better solutions and more detailed reporting back to the participating businesses.

Food fraud can literally be referred to as a global business. In this context, it is important to ensure that the fish of the producer is traceable, and it can be done by utilizing blockchain technology. Blockchain technology is the foundation of cryptocurrencies and could serve as the trustworthy traceability tool, needed in a digitally-driven world. The blockchain is generally referred to as a decentralized ledger, a digital record of ownership and custody. It is decentralized in the sense that no one person or entity owns or controls it-no individual, corporation or government - but it can be shared by everyone, meaning it is 100% agnostic- a pure secure record and source of truth. In cryptocurrencies, blockchain serves as proof of ownership. In the case of aquaculture, with blockchain technology, the supply chain of aquaculture can go digital, enabling full traceability from farm to fork, along with many other advantages. With blockchain technology, the decentralized ledger can be owned by everyone and by no one.

Blockchain-based traceability application is used in testing Best Aquaculture Practices (BAP) programs. Chain of custody involves tracking a product through the supply chain. What blockchain offers to the industry is basically a certain level of trust. Every other technology that existed earlier had a way to be corrupted-database could be altered, individuals could make changes, while with blockchain, the record cannot be changed. Blockchain technology is to be employed in shrimp farming in Andhra Pradesh. It will help the farmers to maintain compliance with exporting standards and help farmers to adopt better practices, eventually leading to better exports. This will also help farmers to get a better price for their produce from exporters. Blockchain simplifies the process of integrating data from multiple applications. Blockchain technology holds a lot of promise for aquaculture but building consensus for a bold technology move among diverse stakeholders is a challenge.

# Effect of dietary supplementation with microalgae *Aurantiochytrium sp*. in microdiet and its effect on growth and survival of *Penaeus monodon* Fabricius, 1798 post larvae

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Shrimp farming plays a major role in the global aquaculture industry and microalgae represent an indispensable part because of its higher nutritional profile. In this study, we evaluated the effects of dietary inclusion of *Aurantiochytrium* sp., a heterotrophic marine alga, on the growth and survival of black tiger shrimp (*Penaeus monodon*). *Aurantiochytrium* a suitable candidate for aquaculture nutrition due to its superior nutritional profile, with about 54 % total protein and 26% total fat on a dry matter basis. Besides, they are rich sources of carotenoid and various hydrolytic exo-enzymes. In the present study, three different micro diets were formulated (iso-nitrogenous and isolipidic) with 50% crude protein and 8% fat and fed to the larvae of *P. monodon*. A total of six treatments each with triplicate were carried out, comprising of control and with different algal inclusion levels (T1- 1% and T2-2%), along with co-feeding with artemia nauplii. After 28 days of the experiment, better growth performance and survival rate were observed in T2, co-fed with artemia nauplii as compared to other treatments, while the lowest growth and survival rate was seen in treatment fed with control diet alone. This study revealed that dietary supplementation of *Aurantiochytrium* sp at a 2% level can substantially improve the growth and survival of *P. monodon* postlarvae suggesting its potential in aquaculture.

# The effect of culture management and stocking density on growth, survival, production and economic performance of white legged shrimp *Penaeus vannamei* Boone, 1931 in semi-intensive culture system

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With the evolution of shrimp aquaculture over the years from traditional, extensive and semi-intensive culture methods to modern intensive culture practices relying on the exotic *Penaeus vannamei* in 2009, India's farmed shrimp production reached the approximate figure of 700,000 tonnes during the period of 2017-2018. The present study was undertaken in the shrimp farms of Ernakulam and Thrissur Districts of central Kerala, India having the area of 1.011 ha each. All the biosecurity measures and CAA protocols were strictly adhered to during the experimental period. Reservoirs were maintained for treating water prior to filling the ponds. There were 5 treatments with 3 replications each. The *P. vannamei* seed was purchased from a private hatchery in Gudur. During the grow-out, high-quality commercial feed pellets were given to the animals as four rations at 6.30 am, 10.30 am, 2.30 pm and 6.30 pm on a daily basis. Farm management included various steps of pond preparation including drying, weed fish eradication, fertilization, water chlorination, prebiotic application, aeration, and feed management. The outcome of the experiment revealed that the stocking density of 15-20 nos./$m^2$ realizing the size range of 35-40 g (25-30 count/Kg approx.) was the most profitable as well as a sustainable system. Sustainability of aquaculture depends on the maintenance of a good environment of combining with excellent pond management and health monitoring which is the key for successful shrimp production.

# Captive breeding of ornamental shrimps *Ancylocaris brevicarpalis* Schenkel, 1902 and *Thor hainanensis* Xu & Li 2014 at Lakshadweep: an addition to marine ornamental aquaculture

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In recent years, the marine ornamental invertebrates gain popularity in the aquarium trade. In order to meet the soaring demand, these shrimps are regularly being caught from the natural habitats especially reef environs. Therefore, an introduction of effective breeding technology is the only solution to tide over this, as it can lessen the pressure owing to indiscriminate collection from the natural system. The present study describes the captive breeding and larval rearing of marine ornamental shrimps; *Ancylocaris brevicarpalis* and *Thor hainanensis* and transfer the breeding technology to the islanders of Lakshadweep, which forms an alternate livelihood option, besides conserving biodiversity potential too. To achieve the primary objectives of the study, *Ancylocaris brevicarpalis* and *Thor hainanensis* were collected from Agatti Island, Lakshadweep, by adopting eco-friendly methods. *Ancylocaris brevicarpalis* found generally in symbiotic association with the anemone, *Heteractis magnifica* and a similar habitat were emulated in the experimental set up as well. After intensive domestication, the larvae hatched out to the zoeal stage and then as decapodid and further metamorphosed within a month as a miniature adult. Fecundity was 700-800nos. The larval survival was 50-60 % and the juvenile with 45-50%. With regard to *Thor hainanensis*, it is a newly reported shrimp from Indian waters by the ICAR-NBFGR. It has good potential to be introduced as an ornamental organism into the aquarium trade since captive breeding of *T. hainanensis* has never been attempted in India or elsewhere hitherto barring a study related to its diversity. Broodstock development could be achieved with three months and it was observed to be a continuous spawner and the fecundity is 200-250. The larva came across zoea and decapodid stages and attained metamorphosis in 40 days. Larval survival was 60-65% and juvenile production was 60%. Both the larvae were fed on Copepod followed by *Artemia* naupili and subsequently with enriched *Artemia* and squashed mussel meat. The juveniles are performing well with the FRP tanks and trials are on to achieve maximum survival of juveniles by modifying the culture conditions. Opportunities and challenges on the said topic are also discussed at length.

# Comparative growth and biochemical responses of Indian pompano *Trachinotus mookalee* Cuvier, 1832 cultured in integrated cage cum pond and pond culture systems

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Integrated cage cum pond culture is one of the important methods for fish culture. Indian pompano is one of the candidate species for aquaculture and can be cultured in different culture systems. An experiment was conducted to culture the fish in two different culture systems for a period of 300 days with an objective to compare its growth and biochemical responses. Two one acre ponds were used for the study, in which one pond was directly stocked with 3000 numbers of Indian pompano (35 g). The second pond used for integrated cage cum pond culture, where four cages were suspended. The cages were stocked with a total of 4000 fishes, @1000 numbers/cage and 1000 fishes also were directly stocked in the same pond. Initially, fishes were stocked in 4x4x1 m cages @40 numbers/$m^3$ till fish reaches 250 g and thereafter fishes were stocked in 8x8x1 m cages @15 numbers/$m^3$ for the remaining culture period. Fishes in pond and cage were fed four times in a day with pelleted feed containing 40-45% crude protein and 10% crude fat. Periodical growth and other biochemical parameters at the end of the culture trial were estimated to understand the growth and health status of the fishes in different culture systems. The mean weight of the fishes after 10 months of the culture was 358±0.21gm, 584±0.08gm for pond and integrated cage, respectively. The grow performance in terms of absolute growth rate, AGR (g/day), specific growth rate, SGR (% /day) and feed conversion ratio, FCR were significantly ($p<0.05$) high for fishes cultured in integrated cage cum pond culture (2.91±0.025, 1.83±0.015 and 1.57±0.025) compared to pond culture alone (1.74±0.015, 1.53±0.15 and 1.92±0.03). The serum biochemical parameter like cortisol, glucose, albumin, globulin, and minerals (% of calcium and phosphorus) were also estimated. The estimated glucose (45.12±0.5, 43.04±0.48 mg $dL^{-1}$) and cortisol (37.08 ± 0.125, 28.57±0.51 ng $ml^{-1}$) in the pond and the integrated cage were significantly different ($p<0.05$). The result revealed that the fishes cultured in integrated cage cum pond perform better compared to the pond culture method. Integrated cage cum pond culture could be adopted as an alternative method for fish culture to further enhancing fish production.

# Life history traits of the marine cyclopoid copepod *Dioithona oculata* (Farran, 1913) under laboratory conditions

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Copepods are good live feeds with high nutritional quality and digestibility. The present study was undertaken in the Vizhinjam Research Centre of ICAR-CMFRI, Kerala. Prior to the study, the wild copepods (*D. oculata*) were collected from Vizhinjam bay and reared for several generations to acclimatize to the hatchery conditions. The culture was maintained at a salinity of 35 ppt, temperature within a range of 24-29$^0$ C, pH ranged between 8-8.5. The mixed microalgae such as *Nannochloropsis oculata* and *Isochrysis galbana* were given as feed. During the time of experiment 100 gravid females were kept in 10L containers with mild aeration and mixed microalgae as feed. After 24hrs all the nauplii were separated from the adults through serial filtration using mesh size of 125μ and 45μ. The nauplii collected were equally distributed in 14 containers of 1 L capacity and maintained until it completed its life cycle. From these containers, subsamples were taken in every 6hrs of intervals and were recorded and preserved in 5% formalin for further examination. Body size (length and width) of each stage including adults, naupliar (N1-N6) and copepodid stages (C1-C5) were measured and photographed. Each stage was identified by observing the morphological details and the duration for each molt was calculated and recorded. The clutch size was calculated by removing a pair of egg sacs from matured females and counting the number of eggs per sac using a stereo zoom microscope. All the stages and eggs were measured using image analyzing software under a compound microscope. The frequency of egg sac production and viability of eggs were also monitored frequently.

Postembryonic stages of *D. oculata* showed prominent size differences in its successive stages. The length and width of naupliar stages ranged from 100-200 μ and 50-110 μ respectively. However, during the development of nauplius to copepodites, a steep increase in length and width were noticed. The mean length and width of copepodites ranged from 300 μ-600 μ and 110 μ-200 μ respectively. *D. oculata* exhibited a clear sexual dimorphism from the C5 stage. Males and females were distinguished from each other by the presence of a geniculation in the antennules of males and a pair of egg sac in females. The females ranged from 640 μm to 720 μ in length and 190- 260 μ in width and in males from 590 μ to 680 μ in length and 170-200 μ in width. Each life stage has visible morphometric differences.

Duration of postembryonic development of *D. oculata* a steady change in the colour of eggs with maturation was also noticed. It was observed that hatching occurred only after 24 hrs of egg development. *D. oculata* has a synchronized pattern of egg development. Post-embryonic development is not isochronal. The developmental duration from N1 to C1 was observed as 5-6 days. The shortest duration of the nauplii stage 10-12hrs was observed in the N1 stage and is the non-feeding stage. The subsequent stages after N1 showed a different time interval for its development. Each copepodite stage took 24 hrs to complete its stage except the C5 stage which took 40hrs. The adult life span is about 20 days. The eggs were small and spherical measuring 65-70 μ in size. The clutch size (the number of eggs per sac) was calculated as 7-10 numbers. The average size of an egg sac is measured as 174μ length and 128μ in width. The frequency of egg sac production is 6-7 times over its lifetime.

# Is aquaculture a sustainable alternative to existing fishing methods?

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Fish production techniques have evolved over the period to meet the demands and survive the competition. In recent decades, several mechanized boats and trawlers came into existence that uses fossil fuel which made the fishing industry as one of the significant contributors to carbon emission. Aquaculture is one of the alternative methods that has evolved for supplementing the existing fish production. Aquaculture has gained popularity in the recent past and has threatened common fishing methods such as mechanized and non-mechanized fishing. There is a need to study and assess the sustainability of dominant fishing techniques and their impacts on the environment. This study aims to assess the environmental impact of dominant fishing methods and to analyze if aquaculture is an environmentally sustainable and economically feasible alternative. To achieve this aim we adopted the methodology as shown in Fig. 1 and this paper majorly focuses on the development of methodology.

We computed and compared the Carbon Footprint (CF) and Life Cycle Cost Assessment (LCCA) as per PAS 2050 for Mechanised and non-mechanized methods for the Worli case study area. We identified the reasons behind the conversion of non-mechanized fishing vessels into mechanized with the help of a case study. Primary data collection was conducted in Worli fishing village, Mumbai, to understand various factors such as the preferable fishing method, fuel consumption, labor and maintenance costs, and fish catch. For calculating the Carbon footprint, we have used PAS 2050 methodology and included the 'Harvest' and 'Post-harvest' phases of fishing within the system boundary, see Fig. 2. Mechanized is found to have larger CF but LCCA shows that mechanized fishing is more beneficial over non-mechanized. The inferences taken from the case study analysis were verified with the general fishing scenario in the state of Maharashtra and India. These scenarios show that India is moving towards unsustainable options such as large crafts and trawlers which are

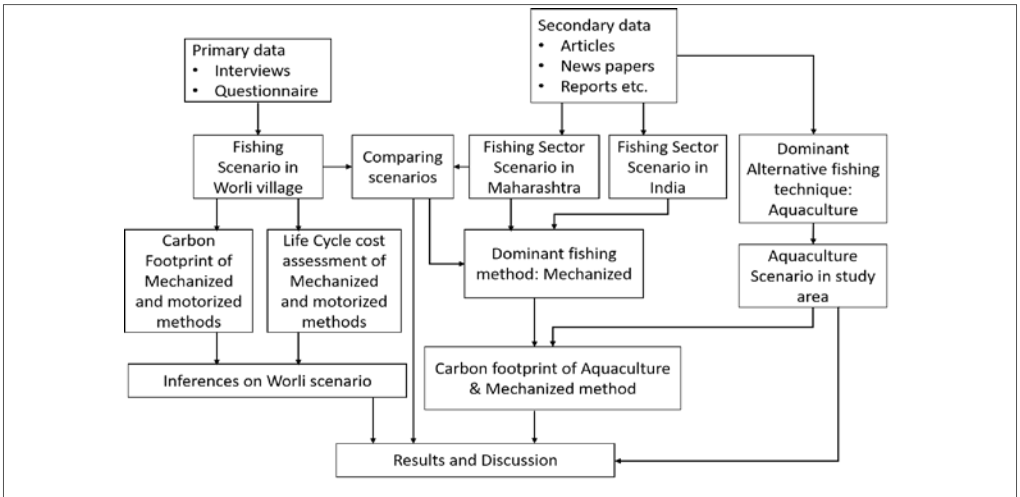


Figure 1. Methodology flowchart

exploiting marine resources and emitting more GHGs.

Aquaculture, which is one of the major alternative fish production techniques in India, is rapidly increasing its production. To understand emissions coming from aquaculture, we calculated CF using PAS 2050 while including feed transport, culturing phase and distribution phase in the system boundary, see Fig. 3. For this analysis, the case of coastal aquaculture ponds near the Vemuladeevi settlement in the Narsapur Mandal in the coastal state of Andhra Pradesh is considered. To understand the environmental impacts, we compared the footprints of the two most dominant fishing methods from our study (mechanized and aquaculture). This study shows that aquaculture has a significantly larger footprint as compared to mechanized fishing.

The growing demands and advancements in the fishing techniques are leading to larger GHG emissions and have a significant impact on climate change. The growing industry of Aquaculture is one of the major contributors of GHGs and the majority of emissions are from feed (FAO, 2016). Aquaculture is impacting the coastal water and soil quality, thus increasing Environmental vulnerability. Aquaculture is water-intensive, discharges organic and inorganic wastes which lead to a higher ecological footprint. Besides GHG emissions, aquaculture involves LULC change and is destroying 'Ecologically sensitive areas' leading to the loss of various ecosystem services. Replacement of mangroves by aquaculture ponds is a major concern (Ashton, 2010; Valiela, 2001). Mangroves are known to provide various ecosystem services such as water quality regulation, protection from coastal erosion, heavy gales and minimize the damage from coastal hazards (Sankar, 2018). Lima & Galvani (2012) and McAlpine *et al.* (2018) found that loss in mangrove cover has led to changes in microclimate: increase in temperature; decrease in atmospheric moisture and decrease in precipitation. From our study, aquaculture is found to be unsustainable due to the larger carbon footprint and has diverse impacts on microclimate. There is a dire need for sustainable measures to decrease carbon and ecological footprints from the fishing industry to reduce impacts on climate change.

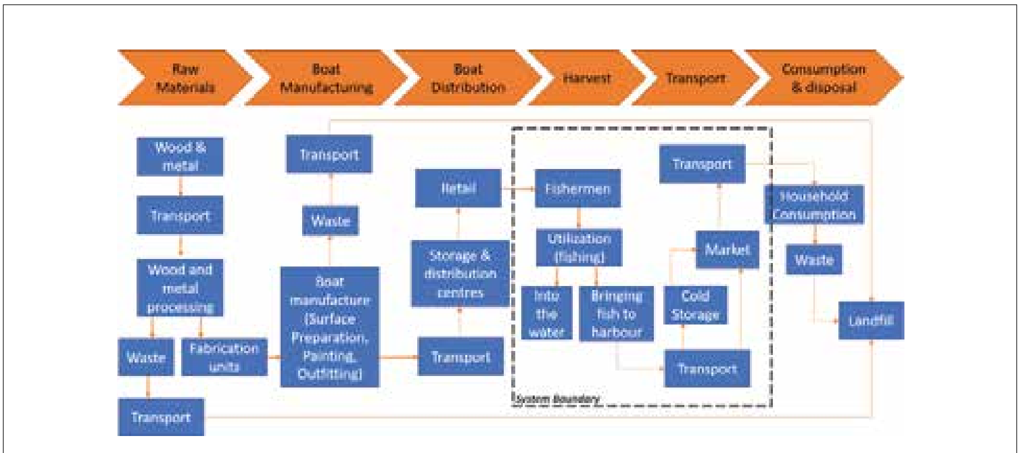


Figure 2 Cradle to gate process map and system boundary for mechanised and non-mechanised fishing

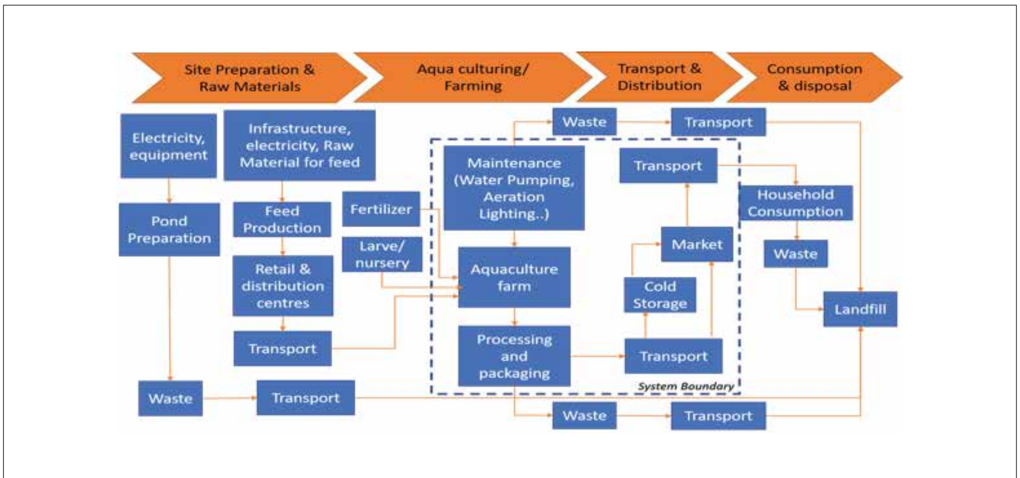


Figure 3 Cradle to gate process map and system boundary for Aquaculture Farming

# Immunomodulatory effect of *Syzygium cumini* (L.) leaf powder on juveniles of Snubnose Pompano, *Trachinotus blochii* (Lacepede, 1801)

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Snubnose Pompano, *Trachinotus blochii* is susceptible to several bacterial pathogens including *Vibrio parahaemolyticus* in the culture environment. In aquafarming, practice, 20 antibiotics were banned and also the application of antibiotics in cage farming is not a feasible practice. Hence, immunostimulant will be the best alternative for the prevention of bacterial/microbial disease outbreaks during adverse climatic conditions. One such immunostimulant is Jamun tree leaves (*Syzygium cumini)* powder that contains several active compounds such as Quercetin, Myricetin, Myricitrin, Triterpenoids and Flavonol glycosides. It acts as a very good antioxidant, antibacterial agent, anti-diabetic, antiviral, anti-cancerous activity and anti-inflammatory agent.

A 45 days experiment was conducted to determine the immunomodulatory potential and disease resistance of *Syzygium cumini* leaf powder in Snubnose pompano. Fingerlings of Snubnose pompano with an average weight of 9.4 ±0.2 g were acclimatized to 7 ppt salinity seawater before stocked into the aquarium (60 × 60 × 50 cm, 180 L capacity) connected with re-circulatory filter assembly. There were four feeds prepared with incorporation of the graded level of *Syzygium cumini* leaf powder (0% SCL, 0.5% SCL, 1% SCL and 1.5% SCL) and fed to four treatments each with triplicates. At the end of the experiment, the experimental fishes were challenged with *Vibrio parahaemolyticus* suspension at a concentration of $1.5\times10^7$ CFU/mL. The growth, enzymatic antioxidant activity, hematological and immunological parameters of Snubnose pompano fed with graded level of *Syzygium cumini* leaf powder in the diet were assessed. Among the four treatment groups, better growth response in terms of weight gain percentage and specific growth rate was noticed in the SCL0.5 group. Similarly, feed utilization parameters such as feed conversion ratio, protein efficiency ratio and feed efficiency ratio were good at the SCL0.5 group.

There was a significant difference (P<0.05) in the respiratory burst activity among the treatments and better activity was noticed in the SCL1 group. The least level of blood glucose was noticed in the SCL0.5 group followed by the SCL1 group. The white blood corpuscles (WBC) level was higher in SCL1.5 and the least level was noticed in the SCL0 group. In the case of red blood corpuscles (RBC), maximum count was observed in the SCL0.5 group followed by the SC1 group. Higher levels of neutrophils and monocytes were observed in the WBCs of SCL1.5 group. There was a significant difference (P<0.05) in the level of enzymatic antioxidants such as superoxide dismutase (SOD) and catalase (CAT) among the treatments. Better SOD and CAT activity was noticed in the SCL1 group both in gill and serum samples. Among the treatments better survival after challenge with *Vibrio parahaemolyticus* was recorded in SCL1 and SCL1.5 groups. This study reveals that *Syzygium cumini* leaf powder at the level of 1% is adequate to import innate immunity in Snubnose pompano and protect against *Vibrio parahaemolyticus* infection.

# Assessment on bioremediation capacity of seaweeds in Recirculatory Aquaculture System

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The present study attempted to explain bioremediation capacity of three seaweeds namely, *Caulerpa taxiflia*, *C. scalpelliformis* and *Dictyota dichotoma* as treatment I, II and III respectively on culture effluent from fish culture RAS unit under poly house roofing. Water quality parameters along with nutrient parameters such as total ammonia nitrogen, nitrite-N, nitrate-N, phosphate and silicate were monitored at regular intervals. Water quality parameters were maintained without any variations. The concentration of TAN in the fish culture unit was recorded almost similar values throughout the period of the experiment. Whereas, in treatments (I, II and III) with seaweeds the TAN value showed a declining trends with increasing biomass of seaweed and DOC. Higher value was recorded in all the treatments only during the initial phase of experiment (up to 15 DOC) and later drastically reduced below the optimum level. Nitrite concentration in the fish culture unit and all treatments was showing a higher value only in the initial days of the culture than the optimum level. Nitrate-N concentration in the fish culture unit was showing a higher value than the optimum level only in beginning of culture. Whereas, in all treatments, nitrate-N higher value were recorded only well below the ideal concentrations. Phosphate levels were recorded higher only in fish culture unit during the initial days. In case of silicate content in both fish culture unit and all treatments were ranged only below the optimum level. Nitrogenous compounds were found to be in a higher concentration fish tank were effectively removed by different seaweeds. Among them, *C. taxifolia* has greater ability to remove nutrient load in comparison with *C. sclpelliformis* and *D. dichotoma*. The increase in biomass of seaweeds was also showed their positive role in the conversion of the nutrients. Better growth performance in term SGR was noticed for *C. taxifolia* (1.854%) followed by *D. dichotoma* (1.559%) and *C. scalpelliformis* (1.361%). The cumulative growth rate was observed more in *C. taxifolia* with other species comparatively with smallest portion of the initial biomass.

# Compensatory growth pattern in stunted fingerlings of mangrove red snapper *Lutjanus argentimaculatus* (Forsskål, 1775) in marine and brackish water

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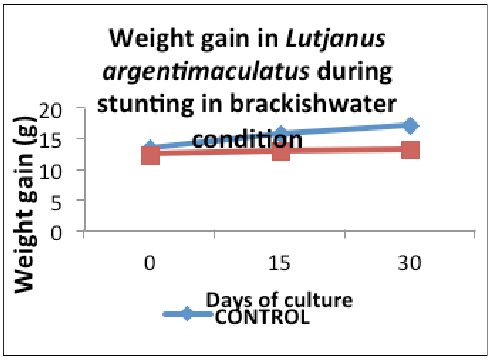
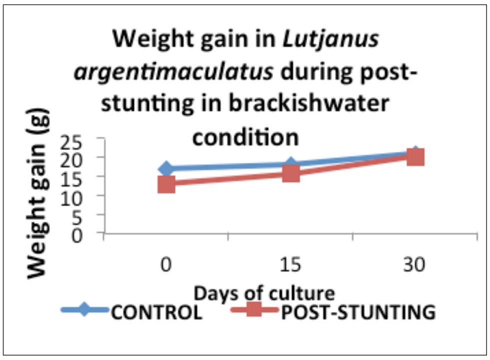
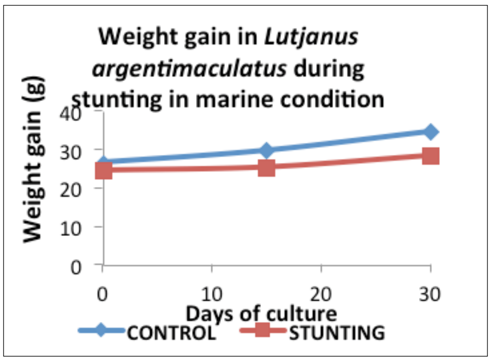
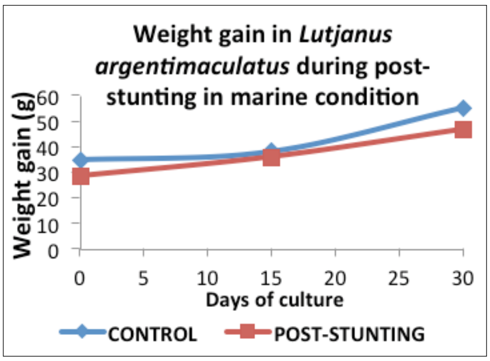
In order to find out the compensatory growth pattern in stunted fingerlings of the mangrove red snapper, *Lutjanus argentimaculatus*, thirty days stunting experiments were conducted in high saline (35 ppt) and low saline (15 ppt) conditions at Calicut Research Centre of ICAR-CMFRI. The fishes were stunted for 30 days at a stocking rate of 50 nos. / $m^3$ providing trash fish at 5 % of body weight and were further reared (post-stunting) for 30 days at a stocking density of 20 nos./$m^3$ providing feed at 15% of body weight. Control was maintained at a stocking density of 20 nos./ $m^3$ providing feed at 10 % of body weight and the fishes were reared for 30 days. The experiment was conducted in three replicates. In high saline conditions, the fishes have grown from a stunted weight of 24.54 g to 46. 71 g compared to control (26.5 g to 55.42 g) in 30 days. In low saline conditions, the fishes have grown from a stunted weight of 12.32 g to 20.54 g compared to control (13.45 g to 21.19 g) in 30 days. *L. argentimaculatus* fingerlings exhibited a compensatory growth pattern when compared to control in low and high saline conditions after one-month stunting with higher compensation observed in low saline conditions.



# Comparative analysis on the usage of hCG and GnRH*a* for induction of spawning in Silver Pompano *Trachinotus blochii* (Lacepède, 1801)

Abdul Nazar A. K.*, Tamilmani G., Jayakumar R., Anikuttan K. K., Sakthivel M., Rameshkumar P., Sankar M., Krishnaveni N., Rao G. H. and Tinto Thomas

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Among the prioritised species for mariculture in India, silver pompano, *Trachinotus blochii* is a euryhaline species and is widely cultured in coastal brackish water ponds in Kerala, West Bengal, Andhra Pradesh and also in high saline waters in Gujarat. The seed production technology of this fish was developed in the year 2011 by the Mandapam Regional Centre of ICAR-CMFRI for the first time in India. The demand for seed is ever increasing since then and hence, further refinement of seed production technology was necessitated to improve the survival percentage of the larvae. The survival and health of the larvae were dependent on the broodstock quality, diets and type of hormone utilized for spawning induction. The broodstock quality was ensured by using fishes without any disease or deformities. This paper presents the recent advances in techniques employed for spawning induction of silver pompano.

Silver pompano broodstock was periodically cannulated for assessing sexual maturity. When at least 25 % of the eggs were in post-vitellogenic stage (above 450 μ diameter), fish was considered ready for induction. The sex ratio was 1 female: 2 males. Both females and males were injected with exogenous hormones for final oocyte maturation and spawning. The induction of silver pompano broodstock was initially carried-out with hCG which is a purified gonadotropin with LH activity and acts directly at the level of the gonads. However, repeated use of hCG resulted in mortality or refractoriness of brooders. Hence GnRH*a* was used for spawning induction. The GnRH*a* is an analogue of gonadotropin releasing hormone and a small peptide with 10 amino acids which acts on the pituitary gland to induce the release of gonadotropins, FSH and LH. The GnRH*a* was used at a single dose of 250 μg/Kg both for males and females. The fertilization rate, hatching percentage and survival of larvae were found to be better than those obtained from the usage of hCG. The brooders could be used continuously for 18 to 20 months at a stretch. The results obtained from the usage of both hormones have been documented.

# Development of a mini-RAS (Recirculatory Aquaculture System) for broodstock development of marine ornamental fishes

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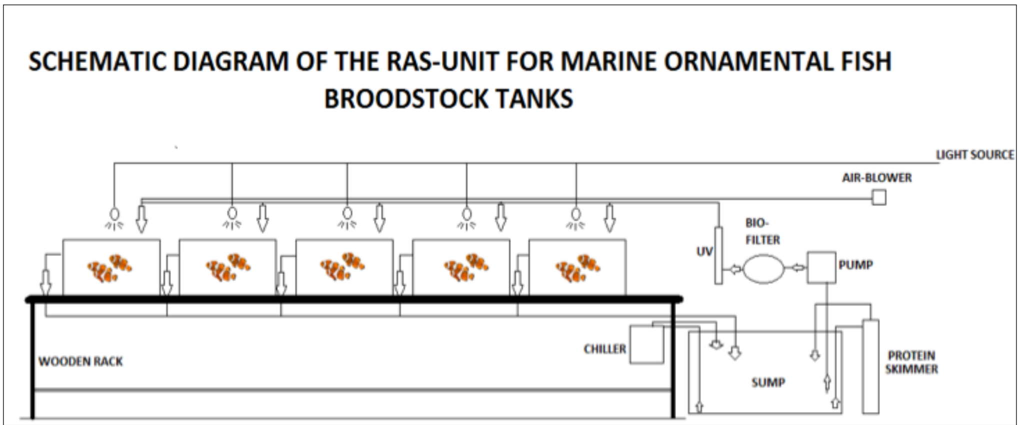
Aquarium keeping is a very popular hobby, the benefits of which have been recognised globally. It is a multi-billion dollar industry and it is estimated that globally around 1.5 -2 million people keep aquaria. More than 2500 marine ornamental species are traded globally, most of which are associated with coral reefs or seagrass beds, mangroves *etc.* Among the most traded families, Pomacentridae dominates with 43% of all fish traded, followed by Pomacanthidae, Acanthuridae, Labridae, Gobiidae, Chaetodontidae Callionymidae, Microdesmidae, Serranidae and Blennidae. The ever increasing demand for ornamental fish has necessitated the development of captive breeding techniques of these fishes and presently most of the popular fishes in the trade have been successfully bred in captivity. The main components of captive breeding techniques include broodstock development, live feed production and larval rearing. Among this bloodstock development and maintenance is the most important thing. The broodstock of the fishes has to be maintained at optimum water quality conditions free from pathogenic organisms in order to condition them for breeding. The natural conditions need to be simulated to make the fishes feel at home which in turn triggers their hormonal pathways for induction of spawning and egg-laying as is seen in nature. This is possible by providing a Recirculatory Aquaculture System (RAS) in the hatchery. The Mandapam Regional Centre of ICAR CMFRI has devised a low-cost technique for setting up of mini-RAS for maintaining the broodstock of marine ornamental fishes. The basic components include a common sump, Bio-filter, UV filter, Chiller, Protein skimmer, Blower, Inlet and outlet assembly for the fish tanks, lighting arrangement for the fish tanks. The total cost of setting up this mini RAS with 16 broodstock holding glass tanks would



be around ₹2.75 lakhs including the cost of wooden racks for placing the glass tanks.

The outlet pipes from all the fish tanks are connected to a common drainage pipe which in turn drains to the common sump. From the common sump, the water is passed through a biological filter followed by a UV filter using a pump and finally, the purified water is fed to the individual fish tanks through separate inlet pipes. A protein skimmer and a chiller are also attached separately to the sump to maintain the water quality as well as to ensure the optimum temperature in the water which is in circulation. The inlet pipes to the individual fish tanks are placed in such a way that the tip of the pipe reaches the bottom of the tank. This ensures proper mixing of the water in the tanks since the outlets are fixed at the top of the water column in the tank. Lighting is provided by installing CFL bulbs of suitable wattage above each tank which could be controlled by a timer to maintain the optimum photoperiod. Adequate aeration is maintained in the tanks with the help of a blower of sufficient capacity and aeration lines. The broodstock pairs maintained with the mini RAS is regularly laying eggs and hence round the year seed production is possible for supplying the fishes to the traders.

# Studies on the maturation and gonadal development stages of Siganid fishes from Gulf of Mannar region, India

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In recent years, there is an increasing interest to enhance aquaculture productivity by using fishes from the lower trophic levels such as rabbit fishes (Family: Siganidae). However, the seed production of these fishes has not yet been developed for which basic information on reproductive biology needs to be gathered. Rabbit fishes form an abundant group in the marine fish landings from the Gulf of Mannar region. The objective of the present study was to describe the phases of gonadal development and determine the spawning season of the fish. Length-weight relationship, gonadal developmental stages and sex ratio of three species, *viz. Siganus javus*, *Siganus canaliculatus* and *Siganus lineatus* have been studied in detail. Annual and monthly changes in the gonadosomatic index (GSI) and the histological features of the testis and ovaries were documented.

Results showed that *Siganus javus*, *Siganus canaliculatus* and *Siganus lineatus* attains first sexual maturity at 24.5 cm, 22.4 cm and 31.2 cm (Total Length) for males and 22.5 cm, 21.6 cm and 31 cm (Total Length) for females respectively. Developmental stages, dimensions and fine structure of sexual cells during the course of maturation were examined microscopically and documented. During the study, five stages of spermatogenesis and oogenesis of the three species were observed and recorded.

# Standardization of the stocking density for stunting of mangrove red snapper *Lutjanus argentimaculatus* (Forsskål, 1775) fingerlings

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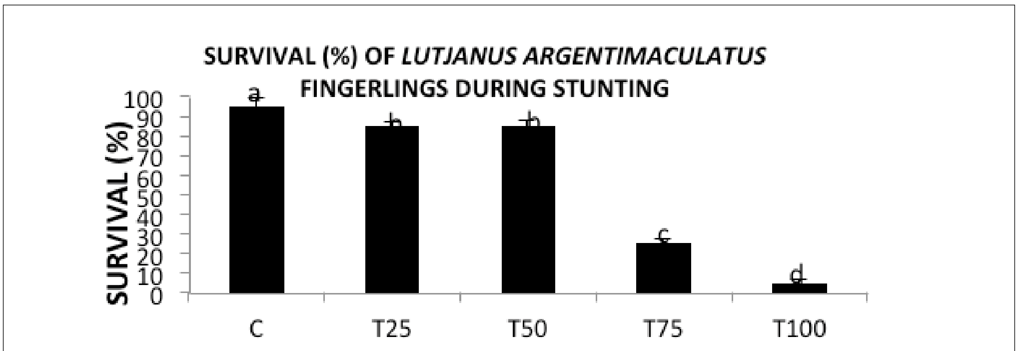
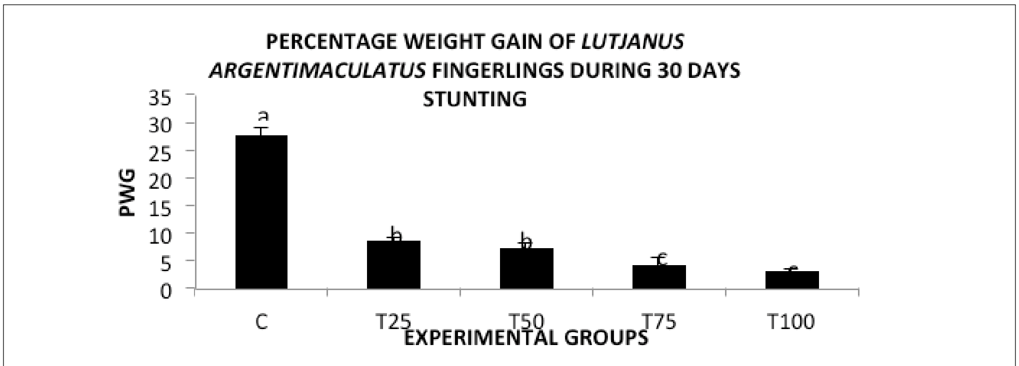
In order to standardize the stocking density of mangrove red snapper, *Lutjanus argentimaculatus* fingerlings for stunted fingerlings production, experiments were conducted at Calicut Research Centre of ICAR-CMFRI. Fingerlings of *L. argentimaculatus* were collected from Kadalundy estuary using bamboo weirs. *L. argentimaculatus* fingerlings weighing 12.38 ±0.94 g were stunted for 30 days at different stocking densities @ 25, 50, 75 and 100 nos./ m$^3$ providing trash fish as feed at 5 % of body weight. Control was maintained at a stocking density of 20 nos./m$^3$ providing feed at 10 % of body weight and the fishes were reared for 30 days. The experiment was conducted in three replicates. The results of the present study indicate that high stocking density stunting is not possible in *L. argentimaculatus* fingerlings. The fishes stocked in tanks with a high stocking density of 75 and 100 nos./m$^3$ showed surface lesions and a consequent high mortality rate. Survival rate was higher in tanks with a stocking density of 25 and 50 nos./ m$^3$. The percentage of weight gain in tanks with a stocking density of 25 and 50 nos./m$^3$ showed no significant difference. Therefore an ideal stocking density observed in the present study was 50 nos./m$^3$ for stunting *Lutjanus argentimaculatus* fingerlings.



# Production of hybrid marine ornamental clownfish *Amphiprion percularis* through hybridisation between female *Amphiprion percula* (Lacepède, 1802) and male *Amphiprion ocellaris* Cuvier, 1830

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Hybridisation of marine ornamental clown anemone fish *Amphiprion percula* (female) and False clown anemone fish *Amphiprion ocellaris* (male) were carried out for the production of hybrid clownfishes under captivity. The broodstocks for the present study were selected from the juvenile produced in the Marine Hatchery of CMFRI, Kochi. After attaining 1.5 years of maturity, females and males were selected for hybridisation experiment. The female of pure breed *A. percula* having size (8.0 to 9.0 cm) and male (4.5 to 5.5cm) of pure breed *A. ocellaris* were reared in 500 lit perspex aquaria fitted with a biological filter and each tank was provided with earthen pots for egg deposition. The pair formation for hybridisation *A. percula* (female) and *A. ocellaris* (male) were achieved through hormonal administration, same tank parental separation method with intermittent pairing, shorter duration of forced parental care method, foster/adoptive father and mother method and manipulation of nutritional parameters through provision of formulated moist feed with high protein and supply of different varieties of enriched live feeds. The pair formed by *Amphiprion percula* (female) and *Amphiprion ocellaris* (male) was successfully bred for the first time in India on 21.07.2017 and the fishes laid 50 to 1500 capsules shaped eggs per spawning at an interval of 10 to 12 days during the period of study. The study showed that year round and consistent breeding was obtained during the period 21.07.2017 to 30.11.2019 (28 months). A total of 66 spawnings with an average of three spawnings per month were obtained during this study period which is of a higher frequency than the normal case (pure breed) in which only two spawnings per month/ pair were recorded. The spawning frequency showed lunar periodicity and it occurred 1 to 8 days after and before the full moon and new moon. The eggs were capsule shaped and contained multiple oil globules of varying size and were pale yellow or white for the initial two days, turned to black on 3rd to 5th day and silvery on 6th to 7th day of incubation. Hatching took place 168 h after fertilization at a water temperature of 28.0 ± 0.5°C. The number of eggs produced, egg fertilization rate, egg hatching rate and the survival rate of F1 hybrids were documented**.** The research for interspecific hybridisation was initiated for producing miss bar variants and designer clown's fishes with mixed colour variants. The unfertilized and fertilized eggs of the hybridised pair were subjected to studying the maternal inheritance. The screening was carried out and subsequently, 10 RAPD primers were used for the present study. The larvae and juveniles obtained through hybridisation were subjected to genetic analysis for confirming hybrid vigour using RAPD markers. Genetic characterization of juveniles produced from normal pairs *A.*

*percula* (Female) x *A. percula* (male) and juveniles produced from *A. ocellaris* (Female) x *A. ocellaris* (male) were also assessed through RAPD markers for comparison with the hybrid clowns. The study confirmed that the juveniles produced are the product of hybridisation between *A. percula* (female) and *A. ocellaris* (male). Morphometric differences in eggs, larvae and juveniles of the hybrid were also documented. The progeny (hybrid) obtained through breeding between *A. percula* (female) and *A. ocellaris* (male) is named as *Amphiprion percularis.* This is the first attempt in the hybridisation of clownfishes under captivity in India in which the parents are generated from the hatchery-produced juveniles. The success achieved in the consistent breeding and hybrid production of clownfish over 5 years of research is a major breakthrough in the marine aquarium trade. Since clownfishes are ground pillars of the aquarium trade and are popular attractions in marine aquaria, the production of hybrids and designer clowns through hybridisation will supply alternate and new source of species for aquarium industry and display. This will also reduce the dependency on wild-collected specimens for the aquarium industry.

# Growth performance and survival of Asian sea bass *Lates calcarifer* (Bloch, 1790) cultured in sea cages at Gulf of Mannar and Palk Bay

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Asian sea bass *Lates calcarifer* is a euryhaline carnivorous fish which can be a potential candidate species for the sea cage farming. Sea cage farming is an alternative livelihood activity being carried out by the fishermen in the Gulf of Mannar and Palk Bay region. The present study was undertaken to evaluate the growth and survival of Asian Seabass *Lates calcarifer* (Bloch, 1790) cultured in sea cages at the Gulf of Mannar and Palk Bay. A total of 5400 numbers of Seabass fingerlings were collected from the wild and transported to CMFRI nursery facility at Mandapam till they attained the stockable size. The fingerlings were stocked in six cages (three each in Gulf of Mannar and Palk Bay) of 6 m diameter with a net-cage depth of 4 m. The stocking density was 8 Nos. per $m^3$ with the average initial body weight of 23 g. The feeding was carried out with low-value fishes @ 8-10% of biomass up to 90 days of culture and 5-8% thereafter. Periodic samplings were carried out to assess the growth rate. The farming was carried out for a period of 9 months. The final growth in terms of mean length and body weight were 48.06±0.59 cm and 1643.64±44.12 g, respectively in the Gulf of Mannar and 50.56±0.66 cm and 1771.58±49.36 g, respectively in Palk Bay. A total harvest of 3.3 and 3.7 tons of fish with a mean survival of 72.5 and 77.3 percent were obtained in the Gulf of Mannar and Palk Bay, respectively.

# Pedigree based genetic evaluation of the captive-bred breeding population of Silver Pompano *Trachinotus blochii*

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Mariculture is the fast-growing aquaculture sector in which seed production and farming of one of the high-value marine fishes, the Silver Pompano is being carried out by ICAR-CMFRI. Genetic management of the breeding population of this species is being carried out at Mandapam, Tamil Nadu. In the study, genealogical information of this captive-bred population was evaluated to assess the genetic variability and the status of inbreeding through pedigree analyses. Although pedigrees are often recorded in fish improvement programs, the implementation of that information as a tool to analyze the genetic architecture of the population is seldom carried out. Data on pedigree information (n=413) for 8 years (2011-2018) were analyzed for the study. Molecular marker (micro satellites) based software program FAP (Family Assignment Program, version 3.6) was used for parentage assignment. Pedigree analysis and estimation of population genetic parameters based on the gene origin probabilities were performed using the software program ENDOG (version 4.8). The study has an implicit reference population against which the parameters were computed.

Generation interval, coefficients of inbreeding and relatedness, individual increase in inbreeding (rate of inbreeding), realized effective population size, effective numbers of founders, ancestors, founder genomes and non-founder genomes and the loss of genetic variability caused by genetic bottleneck and genetic drift were computed. The number of ancestors contributing the most of 50% genes ($f_{a50}$) to the gene pool of the whole population as reference was only 13 which might have led to a reduction in genetic variability. The realized effective population size was 10.53 which is very small and with the increasing trend of inbreeding, the situation has been assessed to be critical. The analysis revealed the evidence on the loss of genetic variability with critical effective population size and resulting in disequilibrium among the founder contributions in the population. The parameters computed from pedigree are needed to assess the quantitative genetic architecture of traits, the status of inbreeding and to genetically manage the breeding population. The results obtained will complement the production variables and provide the basis for a long-term breeding strategy for the Silver Pompano. Recommendations are made to reduce the probability of deleterious effects of inbreeding and to improve the genetic variability in the population.

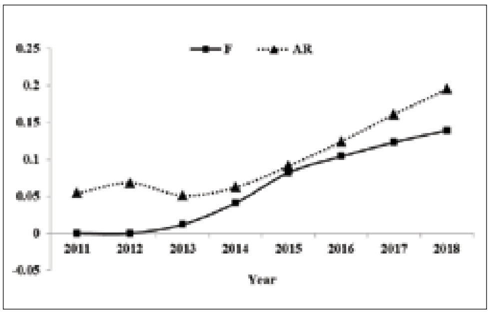


Fig. Trend of the average inbreeding (*F*) and the mean average relatedness (*AR*) over the years for the captive-bred breeding population of the Silver Pompano.

# Growth performance and biochemical composition of Pacific white shrimp *Penaeus vannamei* Boone, 1931 reared in indoor and outdoor biofloc system

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Pacific white shrimp is widely farmed in earthen ponds, plastic-lined ponds, raceways, and recently in Recirculatory Aquaculture System (RAS) and biofloc based rearing systems. Biofloc systems are diverse in nature and offer several advantages in terms of production, economics, and the environment. There are biofloc systems operated indoor without exposure to the direct sunlight, and outdoor systems with direct exposure to the natural photo periodicity, with prospects and constraints in each one of them. However, the functionality of these systems in terms of growth promotion and final product quality remains poorly understood. In this backdrop, this 9-week long feeding trial comparatively evaluated the survival, growth, feed utilization and final product quality of shrimp, *Penaeus vannamei* reared in two different biofloc systems, indoor and outdoor.

The experiment was conducted in free-standing 1000 l self-cleaning microcosm tanks provided with sufficient aeration and air-driven water circulation. Each treatment consisted of three replicate tanks that were stocked with 60 juvenile shrimps (150±0.08mg). Shrimps were fed CIBA's Vannami*plus* feed three times per day adopting the standard feeding ration. Feed ration was adjusted every week according to the bodyweight of the shrimp after each sampling. Wheat bran was used as a carbon source and added at the rate of 60% feed applied to tanks to induce biofloc formation.

Final weight, weight gain, specific growth rate (SGR) and protein efficiency ratio (PER) were significantly ($P<0.05$) higher in outdoor biofloc system than in the indoor biofloc system (final weight 10.10±0.37; 8.28±0.08, weight gain 10.01±0.45; 8.13±0.08, SGR 15.98±0.60; 13.06±0.20, PER 0.28±0.01; 0.23±0.00 respectively). FCR was significantly ($P<0.05$) higher in the indoor biofloc system (1.16±0.01)


Fig. 1 Harvested *Penaenus vannamei* shrimp reared in different biofloc systems. A. Indoor biofloc; B. Outdoor biofloc.

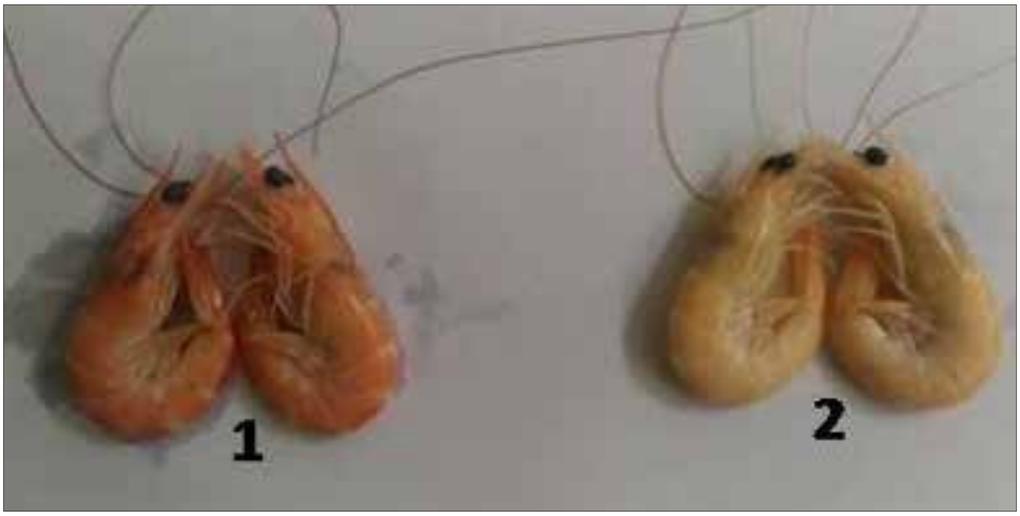


Fig. 2 Pigmentation of shrimp reared in different biofloc based rearing system. 1. Indoor biofloc; 2. Outdoor biofloc reared in outdoor and indoor biofloc system

than the outdoor biofloc system (1.01±0.23), and there was no significant difference ($P>0.05$) in survival among the treatments. There were no significant differences ($P>0.05$) in any of the proximate constituents among the treatments, except the crude lipid. Similarly, the total carotenoid content of shrimp was significantly ($P<0.05$) higher in the outdoor biofloc system compared to the indoor shrimps.

This study has shown a better feed utilization and higher growth performance of the Pacific white shrimp reared in outdoor biofloc system may be primarily due to their ability to get supplementary micronutrients from *in situ* fresh biofloc which is formed by multiple organisms such as phytoplankton, zooplankton, protozoans, and other microbial biomass. On the other hand, the lower growth performances of the shrimps in indoor biofloc system may be due to lower indoor water temperature and lack of green biofloc rich in nutrients compared to the bacterial dominated indoor biofloc. The most promising features of biofloc based rearing systems are they offer increased biosecurity, reduced costs of production for the farmer, and provide a potential opportunity of moving the shrimp culture industry along a path of higher sustainability and environmental compatibility.

# Histological observations on the oocyte development in the picnic seabream *Acanthopagrus berda* (Forsskål 1775)

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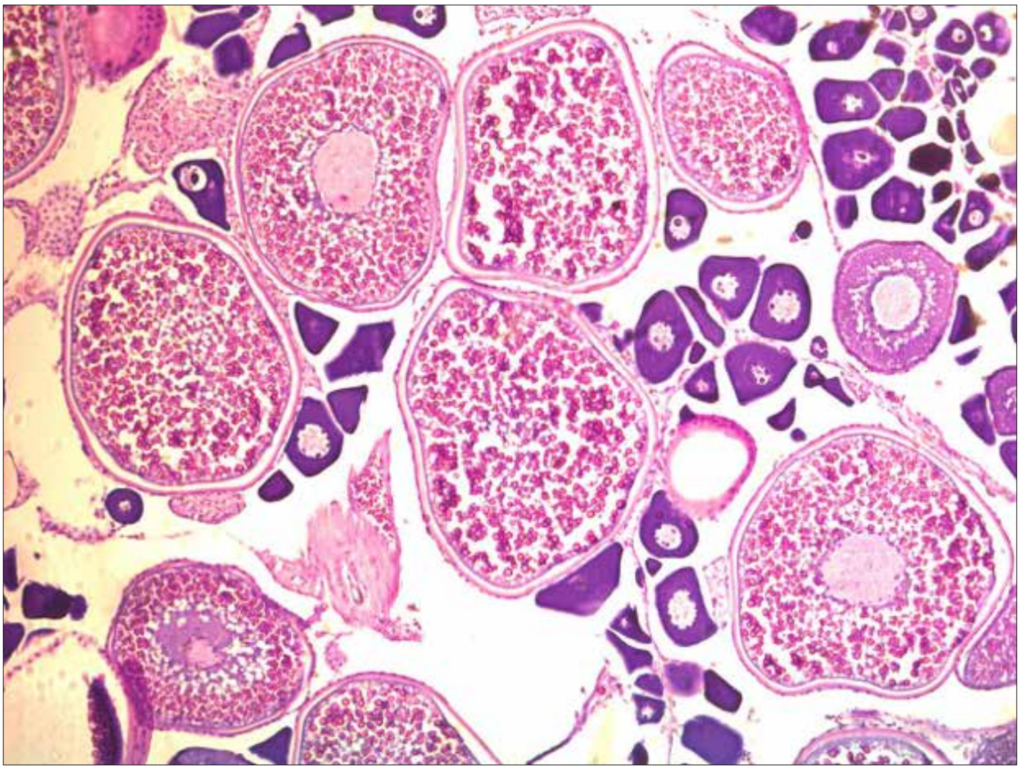
Histological analysis was carried out on ovarian development in the picnic sea bream, *Acanthopagrus berda* (Forsskål 1775) caught in the estuarine waters of Calicut, Kerala, India during January to December 2016. Four developmental phases of oocyte development were identified *viz*, primary growth phase, secondary growth phase, maturation phase, and follicular atresia phase. Oocyte development stages observed in *A. berda* were oogonia, chromatin nucleolus, early perinucleolar, late perinucleolar, lipid vesicle stage I oocyte, lipid vesicle stage II oocyte, primary yolk granule stage, secondary yolk granule stage, tertiary yolk granule stage, hydrated oocyte, and atretic oocyte. Histological examination of the mature ovaries showed the presence of all the different oocyte stages in the ovary of *A. berda* with an asynchronous mode of ovarian development shortly before the spawning, indicating that the species is a multiple spawner.



**Mature ovary of *Acanthopagrus berda* showing different stages of oocytes** (oogonia (O) chromatin nucleolus (CN), early perinucleolar (EPN), late perinucleolar (LPN), lipid vesicle stage II oocyte (LV II), primary yolk granule stage (PYG), secondary yolk granule stage (SYG), tertiary yolk granule stage (TYG), and atretic oocyte (AO))

# Development of hatchery techniques for vermiculated spinefoot *Siganus vermiculatus* (Valenciennes, 1835)

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*Siganus vermiculatus* (Valenciennes 1835) or vermiculated spinefoot is one among the largest growing rabbit fishes, which can be considered as an excellent candidate species for mariculture. They are also suitable for cage culture due to their faster growth rate, tolerance to fluctuating environmental conditions, crowding and handling. These herbivorous fishes can be reared using low protein feeds and can also be used to control net fouling algae in the cages. For successful development of *Siganus vermiculatus* culture, adequate quantity and quality of hatchery-produced seeds are essential. The development of techniques of capture, transportation, acclimation, maturation, cannulation, breeding and larval rearing of *Siganus vermiculatus* is presented.

Wild fishes were captured during the beginning of the reproductive season using stake nets. The fishes were transported to the marine cage farm of Karwar Research Centre of ICAR-CMFRI in Sintex tanks. The fishes were maintained in broodstock cages and acclimatised to formulated pelleted diets. Following cannulation, the mature brooders were introduced to the hatchery complex of Karwar Research Centre of ICAR-CMFRI after prophylactic treatments. The breeding pair was intramuscularly injected with hCG @ 500 IU and 200 IU for females and males respectively following the lunar cycle. The adhesive demersal spherical eggs (av. 560 μ) were found attached to the sides and bottom of nylon hapa and on tiles kept inside the spawning tank. Spawning was observed after 21 hrs and 30 minutes of the final dose of injection. Embryonic development was done in seawater of 28 ppt salinity and temperature of 27-29 $^{0}$C. The initial hatchlings were observed after 25 hrs of spawning. The newly hatched larvae measured 1.713 mm to 1.783 mm with yolk sac and oil globule. Larval rearing was done attempted using pure cultures of marine microalgae, copepods and rotifers. This is the first report of induced spawning and larval rearing of *Siganus vermiculatus* in India.

# Growth performance, survival and feed utilization of Pearl spot *Etroplus suratensis* larvae co-fed with Artemia and micro diets of varying protein levels under controlled conditions

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Nutrition is a dominant factor influencing larval growth; good knowledge of the larval nutritional requirements would contribute to the optimization of diets and feeding protocols, and thereby improving larval and juvenile quality. Problems of the limited number of dry feeds as a supplement or replacement of live feeds have led to poor larval nutrition in many species of fish. Therefore, the study aimed at (1) evaluating the efficacy of live food organism (artemia nauplii) and artificial diets in the rearing of 8-day-old (12.5-13 mg) Pearl spot, *Etroplus suratensis* larvae and (2) to determine the effects of varying protein levels on growth and survival for appropriate rearing conditions for the larvae. The experiment ended after 30 days of culture and respective groups compared on the basis of growth performance, survival, feed utilization and nutrient utilization. Four diets were formulated with 9% crude lipid and different protein levels as follows (D1: 40%, D2: 45%, D3:50%, D4:55% crude protein). There were 8 treatments in total, kept as triplicates. In the first four treatments, the diets D1, D2, D3 and D4 were provided and in the subsequent four treatments, co-feeding was done with live feed (artemia) for the initial 10 days and formulated feed alone subsequently. Larvae co-fed using artemia and 50% protein containing micro diet resulted in significantly better growth performance in terms of, weight gain (700.27 ±7.18), total length (2.03cm ± 0.15), feed conversion ratio (FCR) 1.13 ± 0.57 and specific growth rate (SGR) 14.62 ± 0.12 than other treatments. The lowest growth performance, weight gain (560.05 ±13.85), total length (1.74cm ± 0.15), feed conversion ratio (FCR) 1.66 ± 0.57 and specific growth rate (SGR) 11.67 ± 0.27 occurred in larvae weaned using 40% formulated feed. Better survival of over 90% was obtained in larvae weaned with co fed diets, while abrupt weaning using 100% dry diets resulted in lower survival (<76%). These results support a recommendation of co-feeding *E. suratensis* larvae using a formulated dry diet and artemia nauplii as live feed for the successful culture under controlled conditions.

# Length -weight relation, condition factor and size variation in Silver Pompano *Trachinotus blochii* (Lacepède, 1801) at different rearing phases

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Silver pompano, *Trachinotus blochii* is one of the recently introduced candidates for the marine and coastal aquaculture practices in the Indian subcontinent owing to its standardized seed production technology and established farming practices. Length-weight relationship, condition factor and size variation in silver pompano *Trachinotus blochii* at different rearing phases such as nursery, grow out and marketing stages in two different salinity regimes such as marine (>30 ppt) and low saline conditions (<15 ppt) has been evaluated using the data obtained from different farming experiments. Silver pompano has shown negative allometric growth in all the growing phases in different salinity regimes with *b* value ranging from 2.49 to 2.99. Condition factor (K) (ranging from 1.3 to 2.31) shows that the fish perform well in both marine and low saline conditions in all the growing phases. But size variation (0.36 to 0.54) as indicated by the Coefficient of variation (CV) in weight was higher in all the growing phases in both marine and low saline conditions. The present investigation suggests that the existence of size variation in silver pompano needs to be minimised for its sustainable aquaculture practices through early size grading of the fingerlings at the nursery rearing stage.

# Effect of feed ration on compensatory growth of stunted fingerlings of Indian pompano *Trachinotus mookalee* Cuvier 1832

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*Trachinotus mookalee* is a potential candidate species for marine and brackish water aquaculture possessing high economic value. It is recognized as a promising candidate species for mariculture because of their attractive appearance, fast growth rate, adaptability to culture environment, acceptability to formulated feed, firm white as well as tasty meat and high market demand. The present study aimed to investigate the effect of feed restriction on compensatory growth of stunted fingerlings of Indian pompano. An experiment was conducted for 60 days. Initially, 200 fingerlings (16.85±0.01 g) were maintained in 1t tanks with restricted ration (1% of biomass) for 30 days. Fingerlings fed with 5 % of biomass were maintained as control. Fingerling during stunting for 30 days recorded 15% mortality and in the remaining, maintained initial weight without significant weight gain ($p>0.05$). The control fishes during the same period had a weight gain of 114±0.24%. Further, the stunted fingerlings (120 numbers) were equally distributed into two treatments in triplicates and fed for another 30 days. The treatments followed were stunted fingerlings fed with 3% and 5% of biomass along with the control. Throughout the experimental period, the fingerlings were fed with commercial feed (Growel, India) possessing 45% CP and 10% lipid. Growth performance revealed that the stunted fingerlings fed with 5% of biomass performed better than that of 3% of the biomass. However, there was no significant difference ($p>0.05$) in the growth of the stunted fingerlings fed with 5% of biomass with the control group. Weight Gain (WG) percentage in stunted fingerlings fed with 5% of biomass and control group was 116.38 ±0.54 and 115.61 ±0.71. A similar trend was also observed for Specific Growth Rate (4.96 ± 0.01 and 4.94 ± 0.01). FCR varied significantly ($p<0.05$) with the lowest FCR recorded in stunted fingerlings fed with 5% of biomass followed by stunted fingerlings fed with 3% of biomass and highest was in the control group. Serum albumin followed a similar trend with WG, whereas total protein and globulin increased in stunted fingerlings fed with 5% and 3%, respectively. Significantly ($p<0.05$) higher serum triglycerides was recorded in stunted fingerlings fed with 5% of their biomass whereas the cortisol values were similar ($p<0.05$) in control group as well as in the stunted fingerlings fed with 5% of biomass and the lowest was in stunted fingerlings fed with 3% of biomass. It is concluded from the study that stunting of Indian pompano fingerlings for short duration and further feeding with more feed ration (5 % of biomass) can improve the growth performance with minimum stress.

# Assessment of morphotype variations among the progeny of designer clownfishes

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The largest share of global marine ornamental fish trade is contributed by fishes/shellfishes/ invertebrates collected from the wild. More than 2500 species are traded globally and the contribution of hatchery-produced fishes in the trade still remains at a very minimal level. Only 30-35 species are commercially produced by captive breeding techniques, even though more than 300 species are reported to be bred in captivity. The best possible way to ensure sustainable development of this sector is to slowly shift from capture to culture so that the fishing pressure on the wild fishes and the associated harm to the delicate coral reef ecosystems can be reduced to a great extent. Among the hatchery-produced fishes being traded, the designer clownfishes are very much in demand owing to their attractive designs and colourations, with the trade names such as Picasso, Platinum, Snowflake, Teardrop, *etc.* to name a few. The captive breeding of these fishes have been standardised by the Mandapam Regional Centre of ICAR-CMFRI and the hatchery produced fishes are being supplied to traders. The present study was undertaken to assess the morphotype variations observed in the progeny produced from captive breeding of designer clowns, namely Picasso and Platinum. Monogamous pairs of Picasso and Platinum clown fishes were maintained in separate glass tanks connected to a Recirculatory Aquaculture System (RAS) to ensure optimum water quality conditions. Fishes were fed on special broodstock diets for gonadal maturation and breeding. After egg-laying and completion of the incubation period, egg clutch along with the substratum was shifted to hatching tank. After hatching, the larval rearing and nursery rearing was carried out in separate tanks for each batch of progeny till the morpohotypical variations could be distinguished clearly. The juveniles thus produced were sorted out and grouped into three groups *viz*., Picasso, Platinum and Percula based on morphotypical variations. The proportion of each morphotype in a progeny was estimated. The study extended over a period of 18 months to obtain sufficient data. The results are given below:

Brooders morphotype: Platinum, i.e., both the male and female are platinum clown fish. In this case, the percentage occurrence of Picasso, Platinum and Percula morphotypes in the progeny was 16.57, 75.40 and 8.02 respectively.

Brooder morphotype: Picasso clown fish, i.e., both the male and female are Picasso clown fish. In this case, the percentage occurrence of Picasso, Platinum and Percula morphotypes in the progeny was 44.6, 9.36 and 46.03 respectively.

# Species diversity and technology used in finfish cage farming along West Coast of India

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Fin fish cage farming, likely to reduce the fish supply deficiency in the near future, provides employment and income to local fishermen and is expanding vastly on marine and brackish waters. For promoting the sustainable cage aquaculture practices, a data set was prepared on the species cultured and cage structures used along west coast of India. Seabass (*Lates calcarifer*), Red snapper (*Lutjanus argentimaculatus*), Pompano (*Trachinotus blochii*), Cobia (*Rachycentron canadum*), Grouper (*Epinephelus spp*), Indian Pompano (*Trachinotus mookalee*) and Snapper (*Lutjanus johnii*), Pearlspot (*Etroplus sp.*) are the major species presently used for cage farming. Circular cages made of HDPE and galvanized Iron (GI) and rectangular cages made of GI materials also ensures long term durability for cages. However, most of the cages reported to have poor harvest within the short period of time. Moreover, unavailability of hatchery produced quality seeds on time leads to collection from wild and paves way to reduction in natural fish stock in the water body. The survey highlights that the persons engaged in farming should adhere to best practices for sustainable development of cage farming.

# Unraveling the response of pathogens recovered from diseased cage cultured Nile Tialpia *Oreochromis niloticus* in Kerala to diverse antimicrobials

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The farming of Tilapia is the most productive and rapid growing food sector all over the world. Nile Tilapia (*Oreochromis niloticus*) is one of the popular fish species among the cultured Tilapia and which accounts to around 71% of the total global Tilapia production. Frequent use of antibiotics in aquaculture as a part of prophylaxis and treatment leads to the emergence of antimicrobial resistance. To mitigate the issue, a proper evaluation methods and control strategies have to be implemented. This study was aimed to analyze the antimicrobial resistance of pathogens isolated from the diseased Nile Tilapia cultured in a Cochin fish farm. Phenotypic and genotypic analyses identified the recovered isolates as *Pseudomonas putida, Edwardsiella tarda, Comamonas* sp, *Delftia tsuruhatensis, Aeromonas dhakensis, A. sobria, A. hydrophila, A. lacus*, *Plesiomonas shigelloides* and *Vogesella perlucida*. Shannon wiener diversity index of the isolates was observed to be H' (loge) = 2.58 as determined using Primer-E software. Antibiotic susceptibility of the recovered strains was tested through disc diffusion using 47 antibiotics, which showed an elevated resistance pattern for *Aeromonas hydrophila*, *Pseudomonas putida* and *Comamonas* with higher multiple antibiotic resistance indexes (MAR> 0.3). The minimum inhibitory concentration of antibiotics was calculated as > 256mcg for most of the resistant isolates. All the recovered isolates were susceptible to amikacin, aztreonam, kanamycin, cefalexin, cefotaxime, levofloxacin, norfloxacin, piperacillin and polymyxin-B, suggesting their effective application in the farm.

# Evaluation of growth and biochemical responses of *Cyprinus carpio* reared in inland saline water

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In India around 8.62 million ha of agricultural land has been badly affected by the problem of soil salinity. Salinization of land has led to the under utilization for agriculture, which paved way for Inland saline aquaculture. An experiment was conducted for 60 days to evaluate the growth performances and survival of *Cyprinus carpio* in inland saline water (ISW). 120 No's of fish fingerlings (avg wt 5±0.5 g) were distributed between two treatments (FW-0.5 ppt and ISW-5ppt) in four replicates fed with control diet. The fishes reared in inland saline water (ISW) have shown significantly lower ($p<0.05$) weight gain percentage, and PER than the fishes reared in freshwater (FW). The metabolic enzyme activities (AST and ALT and glucose-6 phosphatase) in the liver was significantly higher ($p<0.05$) in the ISW group. These results revealed that the rearing of common carp in 5 ppt ISW results in significant reduction ($p<0.05$) in growth and increased metabolic stress in common carp. Even though there was a 10% reduction ($p<0.05$) in growth in common carp after rearing in ISW, the study reveals 100% survival of the fish. Thus, it can be inferred that common carp can be reared in inland saline water, which shows a prospective way to utilize the ISW for aquaculture.

# Microalgal concentrate from *Nannochloropsis oculata* (NANN CON): an alternate indigenous approach

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*Nannochloropsis oculata* is a marine micro algae (Eustigmatophyte) playing an important role in seed production of marine finfishes. The algae are used directly for green water larval rearing system and indirectly for rotifer culture in marine finfish hatchery. It is a small sized algae (2-5μm) having fast multiplication rate and rich in Chlorophyll a, Astaxanthin, Zeaxanthin, and Canthaxanthin. *Nannochloropsis oculata*, being a temperate species, mass production of microalgae in outdoor culture systems is difficult during the summer months, but larval rearing for most of the marine finfishes are at the peak during this period. Such difficulties in algal culture during summer months are being overcome by the production of microalgal concentrate which can be used at the time of requirements. Steps involved in the production of *Nannochloropsis* concentrate (NANN CON) includes seawater treatment; Preparation of intermediate culture of *Nannochloropsis oculata* which includes culture medium preparation and inoculation of the culture with conducive environmental parameters; cell harvest by centrifugation, cell preservation and finally viability confirmation. Centrifugation is proven to be the most efficient method (90%) and the cells in the concentrate remains with same shape and nutritional contents as that of freshly cultured microalgae. Centrifugation could accumulate a cell count of an approximately 30 billions/ml from intermediate culture of *Nannochloropsis oculata*. The concentrate was examined after chilling as well as freezing with 0-20% of glycerol as preservative. Chilled NANN CON preserved with 10% glycerol proved advantageous even after five months of storage with more than 80% viable cells. The preserved NANN CON is used in rotifer culture resulted in 1040 nos. of rotifers / ml at the concentration $3\times10^6$ *Nannochloropsis* cells / ml in rotifer culture. The diluted NANN CON was used as inoculums for the indoor culture of *Nannochloropsis* which could reach the cell count of $12 \times 10^6$ cells / ml in culture with chilled cells preserved in 10 % glycerol. Green water system also could maintain ($1\times10^6$) with the addition of chilled NAAN CON directly to the marine finfish larval rearing tanks. Major advantage of *Nannochloropsis oculata* concentrate (NANN CON) over commercial products is that the cells in this concentrate are viable. This cell can be used as inoculum for scaling up the algal culture. Additionally, the cells of the prepared concentrate remain suspended in water column for longer time as like freshly cultured nano-cells, which helps to maintain the water quality in rotifer culture and larval culture tanks based on its use. However, in many of the commercially available *Nannochloropsis* concentrates, viable cells are not maintained and most of the cells settled slowly, which quickly degraded the water quality in the culture environment. The developed NANN CON can directly be applied in mariculture as rotifer feed, inoculum for micro algal culture and for green water larval rearing systems. NANN CON is having good viability, which makes it superior to other commercial products. The economics for production of NANN CON revealed the cost to be ₹1158.46/kg.

# Sea cage farming of scalloped spiny lobster *Panulirus homarus* (Linnaeus, 1758) at Thoothukudi District of Tamil Nadu

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Scientific sea net-cage farming of scalloped spiny lobsters *Panulirus homarus* (Linnaeus, 1758) is being practiced by the traditional fishers of Thoothukudi district, Tamil Nadu from the year 2016 under the technical guidance of ICAR-Tuticorin RC of CMFRI. Galvanized Iron (GI) of 7 m dia and 2.5m depth of inner net (38.5 $m^2$) were moored in two selected coastal fishing villages, Sippikulam (Lat.8°51'21.8724"N; Long.78°14'59.2065"E) and Keelavaipar Sea (Lat.8°59'46.1946"N; Long.78°15'28.5548"E). The wild-caught undersized *P. homarus* (60±12g) from the bottom set gillnet fishery were collected and stocked in three different stocking densities in 9 number of individual net-cages viz., T1 (28 $m^2$/cage), T2 (38 $m^2$ /cage) and T3 (48 $m^2$/cage) in triplicates in the above-installed net-cages. This study elaborates on the grow-out production details of spiny lobsters cultured in sea net-cages according to the stocking densities. The average production from the grow-out cages of different stocking densities was 144.0±24.0 kg (T1), 128.5± 11.8 (T2) and 112.5kg ± 6.3 (T3) respectively. The average daily growth (g) and weight increase (kg) during 140 days of culture period were higher in T1 (28/ $m^2$ ) compared to T2 and T3. The observed mean final weight (T1) of harvested spiny lobsters were 228±12g and 180±10.0g (60 % Grade-I & 30% Grade-II) and the Grade-I percentage in other treatments forms less than 60%. Besides, T2 and T3 represents 10 to 20 % soft shell lobsters (93.0-212.0 g) were recorded however only 5 % is observed in T1. The farm gate price of *P. homarus*, Grade-I and Grade-II were Rs.2100/kg and Rs.1700/ kg respectively [I USD = 71.60 Indian Rupees] and sold as live to exporters. The study reveals that stocking density considered an indicator for the sustainable farming and profitability of this scalloped spiny lobster culture practice in addition to other cage management measures. In conclusion, farming of scalloped spiny lobsters *P. homarus* in 7 m dia GI sea net-cage is a highly profitable venture and it serves as an optional livelihood avenue for the traditional fishers in Thoothukudi district.

# Shrimp farming in India - past, present and future

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The potential area available in the coastal region of the country for shrimp farming is estimated between approximately 1.2 million to 1.4 million hectares. Cultured shrimps contribute about 50% of the total shrimp exports from India. The technology adopted ranges from traditional to improved traditional within the Coastal Regulation Zone (CRZ) and extensive shrimp farming outside the CRZ. About 91 % of the shrimp farmers in the country have a holding of less than 2 ha, 6 % between 2 to 5 ha and the remaining 3 % have an area of 5 ha and above.

Environmental issues have always been the point of debate in shrimp farming. Harvest from capture fisheries having stagnated globally, aquaculture is viewed as a sound option to increase production, and play a vital role in providing food and nutritional security. However, the shrimp farming sector has been strongly opposed by environmental groups on many occasions, not only in India but in many other countries around the globe. Legal interventions have been sought to curtail shrimp culture, to preserve the coastal environment and ecology. Though the polarization of opinion on the adverse impact of aquaculture in the nineties was very strong, of late, there are signs of more tolerance to accommodate diverse views and opinions and to allow development of shrimp farming in an environment friendly and sustainable manner.

Commercial shrimp farming gained a foothold in India only in the late eighties. It was, however, a relatively late entry for India. By then, shrimp farming had reached peak in most of the neighbouring Asian countries, especially China and Taiwan; in some, the disease and poor farm management practices had already taken a heavy toll. The boom period of commercial-scale shrimp culture in India started in 1990 and the bust came in 1995-96, with the outbreak of viral disease. The fact that most of the coastal States in India were new to commercial-scale shrimp farming, the general ignorance of good farming practices, and the lack of suitable extension services, led to a host of problems.

In India, cultured shrimp has been growing at a 30 % per annum at times, since 2010, yet only 9% of the suitable brackish water area is being utilized. India has substantial capacity to expand production. There are new areas to develop for shrimp farming in every state, including the main production area Andhra Pradesh. The west coast, in particular, has many untapped hectares which can be committed to shrimp farming; in the north, the West Bengal region can become an even larger producer; and there are also options in the southern part of India, where three harvests per year are possible.

Secondly, the extensive nature of most operations, is to be considered. The most intensive farms in India stock 50-75 shrimp per m$^2$, which is only half of the stocking density used in China or Thailand. In many parts in the east and north stocking densities are as low as 5-25 per m$^2$. There is a diversity of intensity in shrimp production systems, both globally and within regions. With investment and training, even without devoting new areas to shrimp farming, production can increase in these regions. The key, however, is not to rush into more intensive production systems, without fully understanding the effect on the shrimp and the water conditions.

It must be accepted that the days of

production-oriented shrimp farming are gone. Present day production has to take note of not only the markets but a host of technical issues as well as the concerns of the environment. Sustainable shrimp farming encompasses farm level management practices, integration of shrimp farming into coastal area management, shrimp health management and policy, socioeconomic and legal issues.

Good management practices can make shrimp farming highly sustainable, procedures and methodologies adopted for sustainable shrimp farming have already given encouraging results. These include effective and holistic farm management practices; mandatory requirement for production of hatchery and disease resistant shrimp seed; domestication of broodstock; diversification including alternative candidate species; regulatory framework; community involvement; training and education. Undoubtedly, responsible intensification of production technology and procedures will need to be the keyword, in the way ahead.

# Shrimp aquaculture in India - the way forward

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Aquaculture of shrimps and prawns has made significant advances during the last four decades in many parts of the world including India. In the year 2018 the world produced around 4 million metric tonnes (t) of farmed shrimp which represents around 54% of the total global shrimp production. The global market for shrimps was valued at USD 45 billion in 2018, and it is estimated to register a Compound Annual Growth Rate (CAGR) of 5.2% during the period, 2019-2024.

During 2017-2018, India produced 6.80 lakh t of shrimp through farming. It represents around 17.5% of the global farmed shrimp production. During the last decade (2008-2018) the country registered an unprecedented average annual growth rate of 27.60 % in farmed shrimp production (fig. 1).

In India the development of shrimp aquaculture is not uniform. At present, the states in the East coast produces around 90 % of the total farmed shrimp whereas the share of the states in the West coast is only 10%. The state of Andhra Pradesh alone is responsible for 67.50% of the total farmed shrimp production of the country. The other major contributors in the order of importance are: West Bengal (10.52 %), Gujarat (8.14%), Tamil Nadu (6.42%), Orissa (6.05%), Maharashtra (0.89%), Kerala (0.25%), Karnataka (0.22%) and Goa (0.01%). Productivity of shrimp farms also vary greatly among the shrimp producing states of the county. While the productivity of shrimp farms in Gujarat is 7280 $kgha^{-1}year^{-1}$ that of Kerala is only 541 $kgha^{-1} year^{-1}$ (fig. 2).

In the year 2017-2018 the Pacific white shrimp (*Litopenaeus vannamei*) accounted for 91.5% of the farmed shrimp production of the country. The share of the tiger prawn (*Penaeus monodon*) was 8.5 % only. However the tiger prawn has regional importance and it accounted for 87.98% of the farmed shrimp production in the state of Kerala.

India has 11.60 million hectares brackish water area amenable for brackishwater fish/shrimp production with varying degrees of intensity. Of this an area of 1,52,595 ha. alone is under farming at present. It means that

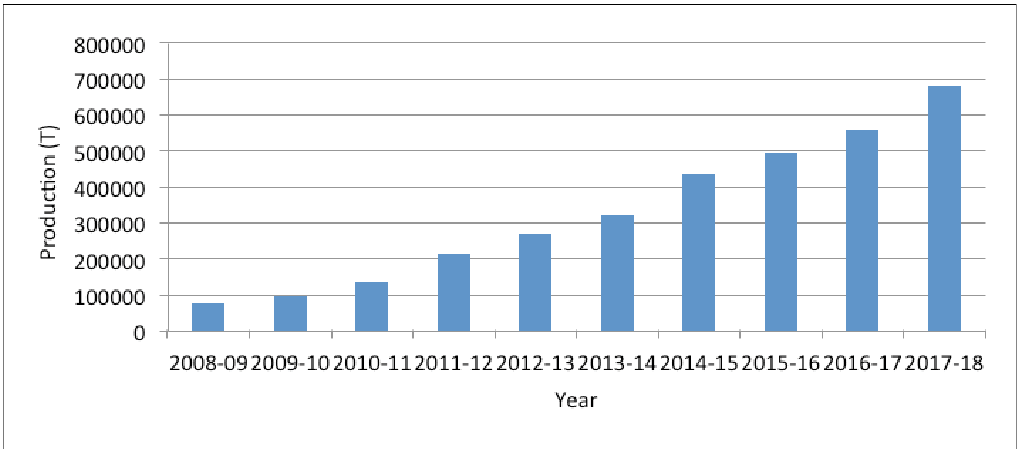


Figure 1. Growth of farmed shrimp production in India during the period 2008- 2018.

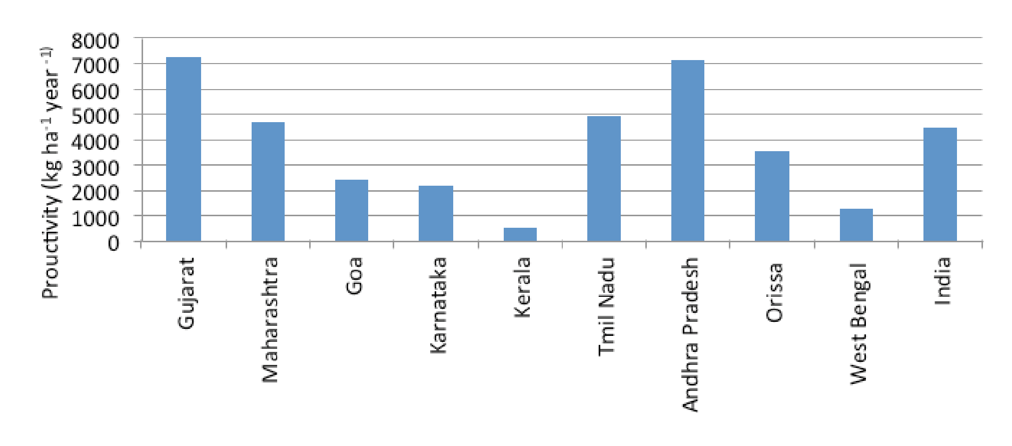


Figure 2. Productivity of shrimp farms in different states of India.

the country has vast untapped resources for further development of shrimp aquaculture. However the development of the sector should be planned in an environment friendly and responsible way with ample forethought, keeping the lessons learned from the collapse of the sector in the early 1990s, in mind. Development of zero-fishmeal based shrimp feed assumes great importance in the context of dwindling marine fish catch and as a strategy to reduce juvenile fishing and by-catch reduction in the marine waters. Therefore, sustainable shrimp aquaculture practices in the country, as elsewhere in the world, would require multi-dimensional approaches which have been mostly lacking at present.

Indian shrimp farming sector till date is predominantly export oriented. But in the wake of perceptible improvement in the economic status and health consciousness of the people there is very good scope for increasing domestic consumption. Except in Lakshadweep and in Kerala, per capita consumption of seafood in India remains low. Domestic consumption-driven development of shrimp aquaculture also helps reduce dependence on single species and ensure equity in development and reduced risk in farming.

India's future potential as global seafood buyers' leading source of farmed shrimp may ultimately be tied to its producers' ability to adopt new technologies and best practices. As the vast majority of the estimated 120,000 shrimp farmers are smallholders, with an average of just three hectare each, uptake of new innovations in breeding, feeding and farm and disease management takes time. In addition, continued expansion of shrimp aquaculture will require healthy coastal and inland ecosystems. Without clear recognition by the farming sector of its dependence on natural ecosystems, aquaculture is unlikely to develop to its full potential.

# Allometric growth patterns in cloudy damsel, *Dascyllus carneus* Fischer, 1885 in captivity

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In India, more than half of the marine aquarium trade is contributed by Pomacentrids alone. The fishes collected from the wild support 90% of the trade, leading to great environmental loss including the coral reef habitats. The aquaculture of principle species involved in the trade will help to reduce the collection pressure from the wild. Hatchery production of marine ornamental fishes is difficult but inevitable. Among the pomacentrids the Genus *Dascyllus* comprises one of the smallest egg producing fishes where the larvae are small, fragile and altricial types. The successful larval rearing depends on the quality of the egg, first feeding, water quality and other management measures. Allometric growth patterns are correlated with physiology, morphology, and life history of vertebrates and invertebrates. It can be used to predict many important aspects such as metabolic rate, dispersal capacity, growth and survival during captive breeding and rearing. Cloudy damsel, *Dascyllus carneus* Fischer, 1885 has been bred in captivity and larval rearing also has been successfully carried out. The allometric growth pattern in the larval development was studied from hatching to metamorphosis. The parameters such as total length (TL), standard length (SL), head length (HL), body depth (BD), eye diameter (ED), Lower jaw length (LJL) and Upper jaw length (UJL) were measured till the metamorphosis.

From hatching to metamorphosis, growth in length (SL) was related to age by a linear function. By this time (0-35 dph) larvae grown from 17 mm to 74 mm. During this period, the body proportion and growth rates have changed significantly. Growth in body depth (BD) differed in 4 different life stages. During yolk sac stage (0-3 dph) growth was nearly isometric (b=1.0168) and during Preflexion period (4-10 dph) allometric growth was positive and increased sharply (b=4.6669). During flexion and post flexion and the growth was again positive (b=2.7949). During metamorphosis the body depth showed a positive allometric pattern (b=1.2634) but not as sharp as flexion and post flexion stages. Head length growth was positively allometric during yolk sac stage (b=2.2239). During preflexion stage the growth rate slightly became less (b=2.0952), but was positively allometric. During flexion and post flexion showed a sharp increase (b=2.749), but during metamorphosis negative allometric growth occurred (b=0.3037). Eye diameter showed negative allometry from 0-15 dph and it varied between b=0.3364, b=0.8282, b=0.8176 for yolk sac, Preflexion, flexion and post flexion respectively. During metamorphosis the growth became positively allometric (b=1.1624).

# Growth, survival and settlement of Asian green mussel *Perna viridis* eyespot larvae at different stocking densities in micro- nursery system

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Micro-nursery system consists of down-welling and upwelling systems(Fig.1 & 2) which can be effectively utilized for mass production of bivalve seed. In the present study down welling system of 2000 l capacity with 4 compartments is used. System consists of 32 wells made of PVC pipes with 150 μ bottom mesh. Wells were stocked with green mussel, *Perna viridis* eyespot larvae in different stocking densities and reared for the period of 120 days to find out optimum stocking density, growth and survival(Fig.3). Eyespot larvae were stocked in 150 μ mesh with 2.0 lakh, 2.5 lakh, 3.0 lakh and 4.0 lakh larvae in triplicates. Larvae were fed with algal mixture (20 to 160 litres progressively increasing during the period of rearing) *Isochrysis galbana* and *Chaetoceros calcitrans* with the cell density of 2.91-3.08 x $10^6$ cells /ml for entire culture period. The percentage survival for the different stocking densities and growth rate were analyzed and presented in this paper.

Fig. 1. Down welling system

Fig. 2. Upwelling system with wells

Fig. 3. Well with grown mussel seed

# Biofloc based nursery rearing of Pearlspot larvae

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Pearlspot (*Etroplus suratensis*) seed production in the hatcheries is not yet commercialized as it's larval and nursery phase growth is very slow especially in high densities. Pearlspot seeds of adequate sizes are always in high demand for aquaculture purposes. Therefore present study was conducted to evaluate the biofloc technology on water quality and growth performance of pearl spot (*Etroplus suratensis*) in outdoor tanks of 13 t capacity at a salinity of 5 ppt. The experiments were done in farmers' fields with control for the comparison of growth, feed consumption and water quality. Nursery rearing of pearl spot seeds was tried in the biofloc systems for a period of 45 days. Biofloc development was done initially by mixing Sugar, with Carbohydrate, vitamins and other mineral materials. One liter of biofloc stock and two litters of jaggery were added to the tanks filled with water and fitted with proper aeration and kept for one week to develop the culture medium. When the pH of the water became 7 and ammonia value was found zero few seeds were introduced to the tanks and examined the conditions for 24 hrs and then rest of the seeds were stocked. Pearl spot seeds of two size groups viz., 1- 2 cm (0.5 -1 g) and 5 - 8 cm (5 - 7 g) were reared in two biofloc systems, growth, feed consumption, floc density and other water qualities were monitored for a period of 45 days. The mean length and weight of Pearl spot *E. suratensis* stocked in the tank 1 were 1.73 ± 0.005 cm to 2.16 ± 0.005 cm and 0.85 ± 0.002 g to 1.08 ± 0.002 g. The second tank was stocked with fishes having a mean length of 4.27 ± 0.005 to 5.61 ± 0.005 and mean weight of 5.03 ± 0.005 to 7.12 ± 0.005 while starting the experiments. The fingerlings were stocked in the experimental tanks as well as in the control systems in a stocking density of 250 no /m$^3$.

In the experimental tanks apart from the *in situ* biofloc, pelleted feed was also given at *ad libitum* at two times in the morning and evening and the quantities consumed were noted separately. In control tanks only pelleted feeds were added at *ad libitum* and 20% of the water with faecal matters was removed daily. Water quality parameters of Salinity, Oxygen, pH and Ammonia were monitored every day and along with all these factors, nitrate, nitrite and phosphate were checked in the lab once a week. The floc volume was measured using Imhoff cone, and the amount of biofloc was assessed daily. The C:N ratio of the biofloc tanks were monitored regularly and adjusted by adding carbon sources. Growth of the fingerlings was analyzed by random sampling with scoop net at intervals of 15 days in both control and experimental tanks. Fortnightly growth sampling was carried out at 15$^{th}$, 30$^{th}$ and 45$^{th}$ days of culture period. From the pooled growth data of pearl spot, length and weight gain, mean length and mean weight gain, and specific growth rate (SGR), average daily growth and total biomass gain were assessed. The mean length varied from 3.87 ± 0.52 cm to 6.58 ± 0.047 cm whereas the mean weight varied from 2.98 ± 0.012 to 5.61 ± 0.035 g in the first tank where in the control tank the growth varied between 1.87 ± 0.52 cm to 3.58 ± 0.047 cm and mean weight varied from 1.18 ± 0.12 to 3.61 ± 0.043 g. In the second size group the growth recorded as mean length varied from 5.87 ± 0.85 cm to 7.85 ± 0.027 cm whereas the mean weight varied from 7.66 ± 0.012 to 11.31 ± 0.035 g. The animals in the control tank recorded mean length of 6.87 ± 0.12 cm to 7.18 ± 0.97 cm whereas the mean weight varied from 4.98 ± 0.17 to 6.61 ± 0.35 g. Ammonia-N level in the biofloc treated nursery rearing tanks was lower (in T1, 0.03 to 0.18 µ/l, in T2, 0.04 to 0.13 µ/l) than control tanks (0.71 to 2.76 µ/l). Nitrate, Nitrite and Phosphate levels also showed a similar pattern.

# Artificial intelligence in aquaculture

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Over the past 20 years, aquaculture production has increased several fold, feed prices have also risen, alongside. Feed cost can account for upto 60-70 % of the total operating costs. Feeding effectively and accurately is a tight rope walk for farmers. Underfeeding lowers growth rates and increases growout duration, while overfeeding increases costs and the growout period. New data analytics technologies such as IoT (Internet of Things) devices and machine learning, can offers smart solutions to the farmer, in this regard. Aquaculture technology providers are now using the power of artificial intelligence (AI), to improve operation efficiencies, in capture as well as culture fisheries.

Internet of things devices, or any of the many things, in the internet of things, are nonstandard computing devices, that connect wirelessly to a network and transmit data. It is a system of interconnected computing devices, mechanical and digital machines, objects, animals or people that are provided with unique identifiers (UID), with the ability to transfer data over a network without requiring human -to-human computer interaction. IoT encompasses the convergence of multiple technologies, realtime analytics, machine learning, commodity sensors and embedded systems. It is, in effect, connecting everyday things to the internet. Real time data, is information that is delivered immediately after collection. Such data is usually processed using realtime computing.

Machine learning, a subset of AI, involves the scientific study of algorithms and statistical models used by computer systems to perform a specific task without using explicit instructions, relying instead, on patterns and inferences. Machine learning algorithms build a mathematical model based on sample data, to make predictions or decisions, without being explicitly programmed to perform that task. Machine learning, also called predictive analytics, is closely related to computational statistics, which focuses on making predictions using computers.

High tech solutions like Artificial intelligence are making steady inroads into aquaculture practices. Feeds and feeding efficiency is a key area of interest. FAI, a real time ocean based fish appetite detection system, is being used in ocean cages. FAI makes use of efficient machine learning and image analysis techniques to extract relevant data from video streams, to accurately quantify fish appetite.

In practice, farmers struggle to monitor and feed all their ocean cages and feed the correct amount everyday, in sea cage culture. This necessitated daily visits to the cages. FAI, a real time ocean based appetite detection system, is being used in ocean based farming sites, under real world conditions for optimizing feeding operations, and for observing the fish 24 hours a day. The unit installed on cages, enables them to check a live stream or saved video data. Farmers can adjust the feeders timings and amount settings to fine tune feeding, check previous feeding and fish data to see the amount of feed used over the past day, week. Using artificial intelligence, the systems can be managed accurately, even when staying onshore, by still monitoring the fish. This involves a smart fish feeder which holds about 400 kg of feed, a solar powered management system, onboard computer, weight sensors, dispensing motors and a camera. Effective monitoring and evaluation of feeding strategies is made possible.

Farmers do have their own apprehensions in completely trusting artificial intelligence, yet apparently, FAI is an important tool to increase productivity and reduce feed waste. The combination of IoT, satellite remote sensing, and artificial intelligence helps farmers to improve farm efficiency, manage environmental risks, and thereby improve revenues.

Aquaculturists are increasingly realizing, that by controlling environmental conditions and system inputs, physiology of cultured species and thereby final process outputs, can be regulated. Anticipated benefits of aquaculture process control and artificial intelligence systems are 1. increased process efficiency 2. reduced energy and water losses 3. reduced labour costs, stress and diseases, 4. improved accounting and improved understanding of the process. AI systems offer the aquaculturist a proven methodology, for implementing management systems, that are both intuitive and inferential, as evidenced by successful commercial applications.

# Influence of suspended mussel farming on the phytoplankton community of Padanna estuary, a major mussel farming site in India

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Suspended mussel farming and its influence on the water quality and phytoplankton community were studied in Padanna estuary, a prominent mussel farming site in India. Sampling was carried out at three major green mussel (*Perna viridis*) farm sites during the pre-stocking (December, 2018) and the harvesting period (March, 2018). Conspicuous variation was observed in both the nutrient and phytoplankton distribution between the two periods. Dissolved oxygen, inorganic nitrate and phosphate concentration exhibited marked variability between the two periods (DO- 7.93±1.09mgl-1 to 9.18±1.75mgl$^{-1}$, $NO_3$- 0.0029±0.0028mgl$^{-1}$ to 0.0222±0.019mgl$^{-1}$ $PO_4$-0.0039±0.0028mgl$^{-1}$ to 0.0129±0.0150mgl$^{-1}$ respectively). The higher phytoplankton biomass (5.59±1.54 mg.m$^{-3}$) and abundance (1.1±0.4×10$^4$ cells/l) of the pre-stocking period reduced considerably and 0.4±0.1×10$^4$ cells/l respectively). No evident variation was observed in the phytoplankton community structure between the two periods. Though diatoms formed the predominant group during both the periods, a decline in their abundance was noticed during the harvesting period (87%) compared to the pre-stocking period (97 %). Dinoflagellates formed the other dominant group during both sampling periods, but had higher percentage contribution during the harvesting period (13%) compared to the pre-stocking period (3%). During both the periods, the diatom, *Skeletonema costatum* formed the dominant species contributing a major share of the phytoplankton population. The study indicates a positive impact on the nutrient status and phytoplankton distribution of a eutrophic estuarine system along south west coast of India due to mussel farming.

Mussel farms of Padanna estuary

after stocking with the *iridis* (2.07±0.53 mg.m$^{-3}$

# Effect of nutmeg fruit extract: growth and feed utilisation in *Labeo rohita* fed with *Chromolaena ordata* leaf meal based diet

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A feeding trial of nine weeks was conducted to evaluate growth response and digestive enzyme activities of *Labeo rohita* fingerling fed with *Chromolaena ordata* leaf meal (COLM) fortified with nutmeg fruit extract (NMFE) as nutraceutical. About 180 fingerlings (average weight 3±0.13 g) were randomly distributed in the four distinct experimental groups in triplicates. Four purified iso-nitrogenous diets (330 g $Kg^{-1}$ CP) with different inclusion levels of NMFE such as G1 (control diet with 30% COLM), G2 (diet with 30% COLM+ 0.5% NMFE), G3 (diet with 30% COLM + 1% NMFE) and G4 (diet with 30% COLM + 2% NMFE) were prepared and the fishes were fed to satiation level for 9 weeks. Among the various groups G3 and G4 exhibited higher ($P<0.05$) feed intake and growth compared to the other groups. However, Growth responses of G4 was not significantly different ($P>0.05$) from G1 and G2. Digestive enzymes activities were significantly higher ($P<0.05$) in the G3 and G4 groups compared to control group. In the present study, feed intake and growth can be improved with supplementation of 1% NMFE in *Labeo rohita* when fed with COLM based diet. Overall results revealed that 1% NMFE can be used as an efficient feeding stimulant in leaf meal-based diets.

# First report of *Argulus quadristriatus* (Arthropoda: Crustacea: Branchiura) infestation in Asian Seabass, *Lates calcarifer*, Bloch cultured in cages

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World-over, infestation of sea bass with sea lice in cages has been a great threat affecting the economy of farming. In this paper, we describe the infestation of Asian seabass cultured in brackish water cages with *Argulus quadristriatus* as a first report. A total of 46 specimens of cage cultured Asian seabass, *Lates calcarifer* were collected from three different locations of Uttara Kannada district, Karnataka. The fish were found to be infected with 22 numbers of ectoparasites in different parts of the body. These ectoparasites were identified and confirmed as *Argulus quadristriatus* based on identification methodology of Devaraj and Ameer Hamsa (1977). The clinical signs in the infected fish included erratic swimming, rubbing against the cage net, hemorrhages on the infected regions. Prevalence, severity of infection, gender status, mean intensity and abundance of *A. quadristriatus* on Asian seabass were studied.

The prevalence (PFI, 50%) of infestation was high in Naganathwada location, which was stated as ‘common’ when compared to other two locations such as Sunkeri and Kumta (PFI, 30% and 7%, respectively). Severity of infection was found to be more in Kumta (2%= Present, very high grade), when compared to Naganathwada and Sunkeri (both 0.5%= Present, low grade,). Gender status and description of *A. quadristriatus* was made and four males and three females were collected from Naganathwada & Kumta, respectively and four males and four females were collected from Sunkeri. *A. quadristriatus* mean intensity of male and female count was 4 and 3, respectively per infected fish which was very high infestation in head region of Asian seabass sampled from Kumta. Mean intensity of male and female was relative less from Naganathwada and Sunkeri (0.6 & 0.6 for male and 0.5 & 0.6 for female). Specific difference between male and female *A. quadristriatus* included a pair of elongated, creamy-white testes with sperm in the abdomen of the male and a pair of round spermathecae in the abdomen of the female. Contrast phase microscopy micrographs revealed some important morphological features of *A. quadristriatus* like four longitudinal stripes, pointed abdominal lobes and the position of the smaller respiratory area was anterior to the larger respiratory area. Histopathological manifestations of the infection included hyperplasia of epidermal and dermal tissue, a high degree of leukocyte infiltration in both epidermal and dermal tissue tissues, hemorrhage at the site of attachment and necrosis in epidermal and dermal tissue.

This study revealed the prevalence *A. quadristriatus* in cage farmed Asian seabass. It was also observed that there was no variation in occurrence and abundance between male and female in all three different locations. There was no record of mortality of cage cultured Asian seabass in any of the farms from where sampling was done. The clinical signs observed could be due to mechanical injury to the skin by the parasite and feeding habit of the lice using its powerful antennae. Care should be taken with management protocols in order to prevent occurrence of these parasites.

# A novel GIS-AHP based spatial modelling for suitable mariculture site selection: a preliminary decision support framework

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The expansion of mariculture in Indian seas has been evident since last decade. Despite the policy deficits, the interest of stakeholder on cage farming has been persistent. The mission initiatives by the Union Government of India and respective maritime states has ignited further to become an emerging sector of the future. The intensification of new activities in territorial waters may lead to sustainability and potential spatial issues. In addition, the demand and usage of sea space may result in escalation of ecological concerns and other cross sectoral conflicts among the stakeholders. So far, the application of GIS in spatial planning for mariculture in India was very scanty. However, in order to mitigate the issues expected, a preliminary decision support framework has been developed. Multi Criteria Evaluation (MCE) modelling was developed for the territorial waters of the Arabian sea coast of Gujarat by using Geographic Information Systems (GIS) and Analytical Hierarchy Process (AHP) application. The transit trajectory of 12 NM territorial sea which accounts an area of 12419.0 NM2 was investigated under the study. There were 14 hydrographic charts digitized for generation of the thematic base map with a scaled contour of the territory. Apart from the biological and oceanographic requirements of the culture system for marine fish production; the navigational aids, defence sensitive zones, sea routes, oil and gas fields, pipelines, river mouths, industry outlets and other maritime utilities were marked, reclassified, optimized and benchmarked for the decision-making analysis. The computational and physical surveys were performed to estimate the occupancy of ports, fishing harbours, various industries, artisanal fishing grounds and other required sector centric spatial criteria. The methodology developed was based on the defined criteria that assess the structural suitability of culture system, biological suitability and accessibility for fish farming operations in territorial waters. The decision-making process and the relative importance of each criterion estimated by revisiting the past institutional experiences, primary scientific literature, formal and informal opinions and interactions with the stakeholders, were executed in AHP. A pairwise matrix for various parameters under five sub models were assessed by calculating the Consistency Index (CI) and the Consistency Ratio (CR). The Site Suitability Index (SSI) for the North-West coast of Arabian sea was derived on MCE procedure by incorporating Weighted Linear Combination (WLC) in the study site. For the extraction of constraint layers, geometric re-classification was done over the determined criteria. To reach final model, five sub-models were developed viz., topographic, socio-infrastructural and oceanographic which comprises physical, chemical and biological models. Through the developed model, potential sites for marine fish farming have been identified. A novel region specific methodological approach was being developed under this study. A gentle slope of <10° found in the depth range of 10-80 m in the earmarked sites was highly suitable for seabed-based installations. The cumulative suitability of more than 50% of the investigated area was found suitable (Most + Moderate suitability) for mariculture development which

shows the untapped potential of the Gujarat coast to promote mariculture activities. In order to validate the process sensitivity analyses of assigned criteria weightage and stability of the model, 200 simulations runs were carried out by using One-At-a-Time (OAT) method. The developed systematic and analytical GIS-AHP-MCE model simulation was precisely stable, effective and delivers an efficient solution by providing a dynamic insight into complex spatial scenarios for mariculture development. The model also supports the integration of mariculture development pre-requisites for an environmentally stable expansion and an ecosystem-based spatial management by considering the views of various stakeholders and existing policy concerns

# Broodstock development, breeding and juvenile production of Banded Coral Shrimp *Stenopus Hispidus* under captive condition

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Broodstock development, breeding and seed production of Banded Coral Shrimp *Stenopus hispidus* (Family: Stenopidae) were undertaken under captivity. The adult male and female (6.0 to 9.0 cm size) were reared in 250 litres glass aquaria fitted with biological filters under 14h light:10h dark, and fed daily with prawn meat up to satiation in three times per day. Daily the pairs were observed for record moulting and spawning, and under captivity the spawning achieved within 60 to 30 days of rearing. Spawning behaviour was recorded and it initiated with antennule contact followed by erection of female abdomen, grasping by male to maintain abdomen to abdomen contact. During mating the male transferred a packet of sperm to the female within 10 seconds of copulation after which the male leaves the female and then the female begins to spawn within 10 to 15 minutes and the eggs are fertilized with the deposited sperms. An average of one spawning/month/pair was obtained in all pairs under captivity. The size of the individual egg varied between 790-840 µm length and 620 to 670 µm width and laid 800 to 1650 nos. of egg/spawning. Three days prior to hatching, the embryos displayed silvery colouration and on the day of hatching, the darkly pigmented eyes become more prominent. The incubation lasted for 16 days at temperature 28°C and hatching took place at night after sunset. One 16th day of incubation, the berried female was placed in hatching cylinder made of plastic mesh with 0.5 mm mesh and the bottom is sealed with Perspex sheet. This cylinder is kept in a circular tank filled with seawater (33 ppt) and given aeration. On completion of hatching the female is transferred to breeding tank without much stress. Soon after hatching the female moults and again new spawning cycle is initiated within 12 to 24 hrs. The larval stage consisted of nine zoeal stage and megalopa stage which undergone 7 metamorphoses in order to metamorphose to an adult. The newly hatched larvae were transparent, pelagic and measured 3.5 to 4 mm with a large dorsal spine which had a backward orientation, eyes fused with carapace and telson with 7+7 setae (Zoea 1). After transferring the female, the larvae were reared in 200 lit circular tank in which micro algae C*heatoceros gracilis, Isochrysis galbana* in 1: 1 proportion at 2x$10^6$ cells/ml were maintained up to 70 days of rearing. The larvae were fed with enriched *C. adriatica* @ 5 to 10nos/ml and newly hatched artemia nauplii (2nos/ml) at $1^{st}$ to $3^{rd}$ day followed by enriched *Brachionus rotundiformis* from $4^{th}$ to $5^{th}$ day @ 3 to 5nos/ml along with newly hatched artemia nauplii (3 to 4nos/ml) on $6^{th}$ to $15^{th}$ day enriched *B. plicatilis* 5 to 10nos/ml were provided along with newly hatched artemia (3 to 4nos/ml). From day 16 to day 45 days, the larvae were fed with enriched *Diaphanosoma celebensis* (neonates) (5 to 7nos/ml) along with newly hatched artemia nauplii (2nos/ml). From $46^{th}$ to $70^{th}$ day enriched adult *D. celebensis* were provided with enriched artemia (2 to 4 nos/ml. From 70 to 120 days, the metamorphosed larvae were fed with shrimp starter feed along with enriched adult *D. celebensis.* At 70 days most of the larvae metamorphosed to juveniles. A survival of 75 to 78% was obtained and from $70^{th}$ day onwards the tanks were provided with coral rocks to hasten settlement. The captive breeding of *S. hispidus* and its commercial production will provide an alternate source of species and it will also help to reduce its fishing pressure in the nature for the aquarium trade.

# Expression analyses of immune response genes in *Carassius auratus* (goldfish) challenged by experimental cohabitation with Carp Edema Virus (CEV) infected Koi Carp

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Koi sleepy disease (KSD) caused by carp edema virus (CEV) is an emerging disease of global concern to common carp and koi carp breeders. Koi carp culture in India is growing rapidly in many states Kerala, Tamil Nadu, West Bengal and Maharashtra. Outbreak of CEV in koi was first reported from Kerala in 2016. A survey was carried out to determine the occurrence and spread of CEV during October 2018 to September 2019 in Kerala. Tissue samples from affected koi were shown negative in PCR screening for common viruses including Cyprinid herpesvirus-3 (CyHV-3), spring viraemia of carp virus (SVCV) and ranavirus reported from koi carp. However, gill tissue from affected koi was found to be highly positive for CEV and sequencing of PCR product also confirmed the infection of CEV and the CEV could not be isolated using koi carp fin, CCKF cell line even after 5 blind passages. Results revealed that prevalence of CEV was widespread and the virus was detected in 35% of koi carp samples collected from five different locations in Kerala. In cohabitation experiment, 15 uninfected goldfish were cohabited with 5 CEV-infected koi carps in a glass aquarium tank and cohabitation with CEV negative goldfish was done as negative control. On the 8 days post-exposure, the presence of CEV was found in the gills of infected goldfish. The mature CEV particles were demonstrated in the gills tissues through TEM. Gill samples were collected at different day exposure (0, 6, 8 and 14 d) to measure the mRNA expression of immune response genes. Significantly higher expression of several immune-related genes (IL1β, IL-10, IL-12, IFNγ-1, IgM, TLR9, TCRα) was noted in different day interval of CEV infection. There was no significant difference in the expression of host TNFα and MHC-II genes during all day exposure of CEV. All CEV exposed goldfish was revealed elicited changes in immune gene expression when compared to control fish. To our knowledge, this is the first report on the expression of immune genes against CEV infection. Our results highlight that the infected koi carp able to transmit the viral disease to other fish through horizontal transmission. This study will help in designing health management strategies to control the CEV in carp.

# Emerging larval health issues in *Litopenaeus vannamei* (Boone, 1931)-A case study

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The increasing trend in intensification and commercialization of shrimp seed production has impacted the epizootics of several larval and post larval infections and diseases in shrimp hatcheries in India. An extensive survey was made to study the emerging larval health issues in *Litopenaeus vannamei* (Boone, 1931) by organizing surveys in major shrimp hatcheries located in Tamil Nadu, Southeast coast of India. Collection of primary and secondary data was done based on the following factors: information on occurrence and history of larval infections and diseases, samples of shrimp larvae from respective hatcheries, data on major water quality parameters, information on the broodstock and larval feed. The survey revealed that several bacterial infections were found to be predominant. The shell degrading bacteria like *Vibrio* spp., *Pseudomonas* spp., *Aeromonas* spp., *Flavobacterium* spp. etc. are known to cause necrosis of body and appendages among the shrimp larvae. Bacterial septicemia in shrimp larvae, caused by *Vibrio* spp., was also reported to occur. Apart from these bacterial infections, in recent times, the prevalence of *Zoea-2* Syndrome in shrimp hatcheries is prevalent in various hatcheries causing impairment in the nutrient absorption leading to delayed molting and mortality of larvae at Zoea 2 stage. Larval and post larval shrimps are commonly are also affected by fungal species *Lagenidium* spp. and *Serolpidium spp.* Besides, protozoan parasites like *Zoothamnium sp.* (ecto-commensals) and *Voritcella sp.* (microsporidia) and gregarines (endo-commensals). In addition, incidence of Larval Deformities Syndrome (LDS) has also become a major problem in shrimp hatcheries, occurring from Nauplius to Post Larval stages. The specific causative agent is still unknown behind this syndrome. Another nutritional problem, known as Swollen Hindgut Syndrome (SHG) had been reported to cause digestive problems in post larvae. Among the various larval diseases and infections listed above, it was found that the most dominant are Zoea-2 Syndrome and Larval Deformities Syndrome followed by bacterial infections caused by Vibrios in shrimp hatcheries disrupting the normal seed production activities.

# Demonstration and participatory bivalve farming in two fishing villages of Tamil Nadu

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A successful commercial farming practice is a blend of scientific management practices and economics. The Central Marine Fisheries Research Institute (CMFRI) has developed technologies for scientific bivalve farming and CMFRI'S collateral effort with State fisheries department, the technologies have been refined and upgraded through many location specific technology demonstrations to make it a profitable aquaculture venture in coastal states in India. The coastal stretch of Tamil Nadu is endowed with large number of east flowing rivers forming productive estuaries offering natural beds of oyster and mussel seeds and also provides sheltered areas for bivalve farming. Though bivalve farming has started long back in Tamil Nadu, regional challenges of low local market demand, limited access to the market in other State and low market price impeded commercialization of the technology. However, in the current scenario there is a marginal increase in market demand for bivalves in big hotels and resorts and also in the local market. Therefore, under livelihood programme Tamil Nadu State fisheries Department with technical support from Madras Research centre of ICAR-CMFRI has again attempted to popularise the bivalve farming technology by involving local fishermen in two fishing villages *i.e.* Senjiamnagar in Tiruvallur District and Kottaikadu in Kancheepuram District which will facilitate additional income through farming and enhance their socio-economic status. The successful harvest of cultured edible oyster, *Crassostrea madrasensis* and green mussel, *Perna viridis* under technical support of CMFRI widened the scope for scientific bivalve farming in Tamil Nadu.

# *Oithona brevicornis*- a candidate species of copepod as live feed for marine fish hatchery

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Copepods are excellent live feed in the marine environment. Recently copepods are being produced in the hatchery and utilised for feeding marine fish larvae. Mostly calanoid copepods of the genera *Acartia* and *Parvocalanus* are popular in the hatchery sector. Cyclopoid copepods of the genus *Oithona* also received good attention as a live feed in several experimental trials. Cyclopids are more hardy and can be cultured in small containers. Few reports are there regarding the production of *Dioithona rigida*, *Dioithona oculata*, *Oithona similis, O. davisae and O. nana*. Unlike calanoid copepods, these are not being widely accepted and utilized as live feed in commercial level. The main reasons are the difficulties in large scale production, larger naupliar stages and their predatory nature. Here we have isolated and standardised the mass production technique of a cyclopid copepod *Oithona brevicornis* suitable for mass scale production for marine fish hatchery.

The copepods were isolated using a stereozoom microscope from the plankton samples collected from Vizhinjam bay and base culture was started in 1 litre transparent beakers under the indoor conditions. After developing the base inoculum for about a month, the culture was upgraded to 30-50L bins and permanently maintained as stock culture in bins. The stock culture was maintained for at least 2-3 months period and after every three months fresh stocks should be prepared from the stocked in a fresh container. The stock of 20-30 litres was used as inoculum for 1000-3000 litre tanks and within 15-20 days tanks became ready for harvesting. Aeration, water exchange and waste removal are essential for stock culture and mass culture tanks. Salinity, 30-35ppt, temperature 24-29°C, pH 8-8.5 and 12hr normal light conditions were found ideal. Mixture of algae *Nannochloropsis oculata* and *Isochrysis galbana* in the ratio 2:1 with a cell density 10000-20000 cells/ml is ideal for feeding.

Naupliar stages of *O. brevicornis* ranged from 65-125µm in length and width ranged from 35-95µm. This is the suitable size range for feeding altricial type of fish larvae of groupers and snappers. This species is more lean (170-200µm), more delicate and slow moving compared to other oithonids. *O. brevicornis* possess all the essential qualities of an ideal live feed. This species is hardy, tolerant to wide range of salinity and temperature. This is productive species with consistently high sex ratio for females in culture. Within 15-20 days it can reach highest density in normal mass culture conditions like calanoid copepods. *O. brevicornis* generally occupy the entire water column evenly; hence this is ideal for feeding even week fish larvae. The stock and mass culture of the species has been standardized at Vizhinjam Research Centre. Experimental trials indicated that this species perform equally well like *Parvocalanus crassirostris* for first feeding of fish larvae.

# Vertebral deformities in hatchery produced Indian Pompano, *Trachinotus mookalee* (Cuvier 1832)

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Skeletal deformities in finfish hatchery affects external morphology, growth and fish survival, which eventually downgrade the hatchery production. Indian Pompano is one of the important candidate fish species for aquaculture, and some of the hatchery produced juvenile fish had exhibited different kinds of skeletal deformities. Therefore, the present study was aimed to understand types of vertebral deformities among the affected fishes, and also investigate the differences in growth performance and essential mineral content in deformed and normal fishes. In a batch of hatchery produced Indian pompano 4.4% of fishes had musculoskeletal deformities. Among which 75.45% were manifested in the form of a deep depression in the musculoskeletal tissue anterior to dorsal fin, 17.27% of juveniles had the depression anterior to anal fin and 7.2% juveniles had the depressions anterior to both dorsal and anal fins. The photo-radiography examination revealed that the fishes with depression in dorsal and ventral fin region formed by fusion of dorsal spines 5-11, and anal spines 1-4, respectively. Fishes with depression in both dorsal and anal fin were affected by lateral and ventral curvatures of the vertebral column between 1-10$^{th}$ vertebral bones. A two months growth study revealed that the fishes of 31.62 ± 0.32 and 29.62 ± 0.18 gm had attained the size of 104.29 ± 0.28 and 102.36 ± 0.19 gm for deformed and normal fishes, respectively. The estimated growth parameters, SGR (1.86, 1.93% / day) and % WG (229.82 and 245.57) were not significantly differentiated ($p>0.05$) for deformed and normal fishes, respectively. However, the vertebral bone mineral content showed significant difference ($p<0.05$) between normal (35.65%) and deformed (32.23%) fishes. Similarly, the estimated calcium (Ca) and phosphorus (P) content in vertebral minerals of normal fishes (22.18% & 11.30%) were significantly high compared to the deformed fishes (20.45% & 10.02%). Plasma levels of Ca & P also showed significant difference (<0.05) between normal and deformed fishes. The study revealed that the minerals play important role in vertebral deformities in fish. However, further studies including genetic factors to be explored in order to address the deformity issues in hatchery produced Indian pompano.

# Marine spatial planning (MSP) for Mariculture development in territorial waters: a preliminary sector centric ecosystem-based approach

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Marine Spatial Planning (MSP) is being developed to support the efficient, effective and sustainable management of ocean ecosystem. Particularly, it aims to establish the cooperative interactions between ocean space, its users and the marine environment. The concept of MSP is yet to get adopted in the mariculture development of the territorial seas of the Indian sub-continent. The expansion of mariculture activities along the territorial coastal waters of the country is been hindered due an ever increasing competitive demand for coastal sea space for multiple users. The expansion of this emerging activity can upsurge the pressure on the ecosystem, which may prompt to an ecological concern and also will leads to sectoral conflicts among the multiple stakeholders. The marine space of the state of Gujarat is intensely used for diverse trades. Stable growth is forecasted for the upcoming years for various maritime sectors including mariculture. To deal with the future developments besides its apprehensions to harness sustainable blue economy while adopting the ecosystem-based developmental approach, a preliminary sector centric marine spatial plan was developed. A GIS based model mariculture spatial grid of 10 km$^2$ (covering 1000 hectare) was developed for the territorial waters form a part of the North-eastern Arabian Sea Coast of Gujarat for the first time in India. The computational tools i.e., Geographical Information Systems (GIS), remote sensing data, and institutional experiences on farming system, species and formal and informal stakeholders' perspectives were integrated in this exercise. This study also depicts the existing state of technical, methodological, scientific knowledge on integrating the region- specific physical, oceanographic, socio-infrastructural challenges and dynamics in MSP through a systematic process derived to achieve a model grid. Such introduction of a new spatial planning framework for mariculture development in territorial waters was in response to the ever increasing interest in new developments and the growing demand for effective and sustainable management of ocean space and its holistic governance. From this study we propose a tier-approach to develop the spatial plans by including multiple response variables and modeling scenario to address socio-political, environmental and governance dynamics within MSP. This preliminary spatial plan developed could be useful for deriving a strategy frame work for mariculture spatial policy and legislation for the respective maritime states to tap the potential of seas while managing a safe and secured ocean heath for the future. Subsequently, it could initiate simple sector centric MSP to complex, then to comprehensive marine spatial plans to Indian seas. This can be adopted and upgraded to recent developments, experience acquired and the new fangled societal demands which back a strong stakeholder involvement. The model GIS based spatial grid for mariculture development in the territorial sea space presented under the study can be a model for mariculture cluster development and future readiness for imbibing the sustainable development and ocean governance. As the comprehensive MSP including all sectors are still in their infancy in the country, this sector centric MSP would be a beginning platform for the initiation of MSP in India. This model/concept is adaptable and can also be useful for other maritime states where such region-specific techno-scientific, and socio-political scenarios prevailing.

Theme 3

# Marine biodiversity assessments and valuation

mbai-mecos 3

# Is Wildlife (Protection) Act, 1972 effective in conservation of marine species in India?

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In India, protection of plants and animal species is enacted through the Wildlife (Protection) Act, 1972 (WLPA) by the Ministry of Environment, Forests and Climate Change, Government of India. Amendments to the Act have also been issued from time-to-time for conservation of endangered and threatened species. So far 885 species of marine fauna belonging to 8 phyla (Porifera, Cnidaria, Arthropoda, Mollusca, Echinodermata, Pisces, Reptilia and Mammalia) are placed under Schedules I, II, III and IV (Table 1). In addition, the Act also empowers the central and state governments for setting up of three types of Protected Areas (PA) namely, Wildlife Sanctuary, National Park or Closed Area. India has 31 marine and coastal protected areas, 18 of which are under marine environment and the other 13 are also partly on land. The 31 protected areas cover an area of 6,271 sq.km.

Marine species protected under WLPA

| Phylum | Group | No. of species | Schedule of WLPA | Interferences |
|---|---|---|---|---|
| Porifera | Calcareous sponges – all species | 10 | Schedule III | Affected by diseases and seawater warming |
| Cnidaria | Reef-building corals (Scleractinia) | 519 | Schedule I | |
| | Black corals (Antipatharia) | 8 | Schedule I | |
| | Organ pipe coral (*Tubipora musica*) | 1 | Schedule I | |
| | Fire corals (Milleporidae) | 5 | Schedule I | |
| | Sea fans (Gorgoniidae) | 86 | Schedule I | |
| Arthropoda | Robber crab (Decapoda) | 1 | Schedule I | - |
| | Horseshoe crab (Merostomata) | 2 | Schedule IV | Illegal removal and trade |
| Mollusca | Gastropoda | 20 | Schedule I, IV | |
| | Bivalvia | 4 | Schedule I, IV | |
| Echinodermata | Sea cucumber (Holothuria) | 163 | Schedule I | Illegal removal and trade |
| Pisces | Elasmobranchs (sharks and rays) | 10 | Schedule I | Incidental capture in fishing gear |
| | Giant grouper | 1 | Schedule I | |
| | Sea horses | 23 | Schedule I | Illegal removal and trade |
| Reptilia | Sea turtles | 5 | Schedule I | Incidental capture in fishing gear |
| | Saltwater crocodile | 1 | Schedule I | - |
| Mammalia | Whales, dolphins, porpoise, dugong | 26 | Schedule I, II | Incidental capture of dolphins in fishing gear; dugong targeted occasionally |
| Total | | 885 | | |

Schedule I and II are for endangered species and provide absolute protection from hunting and trade and offences under these are prescribed the highest penalties. Species listed in Schedule III and IV are not in danger of becoming extinct, but are protected like Schedule I and II species, with much lower penalties. Thus, all the 885 species, irrespective of the Schedules to which they belong to, are protected equally from hunting and trade, and the difference between the Schedules is the level of penalties for violation. In addition to the WLPA, some species are protected by other conservation measures. Sponges, corals and sea fans are distributed mostly in Marine Protected Areas, and thereby they receive additional protection from human interference. For protection of sea turtles from incidental capture in fishing gear, use of Turtle Excluder Device (TED) in trawlnets is advocated in addition to ban on fishing during mass nesting season and restrictions on construction activities in the nesting sites. However, these measures are not very effective as a large percent of turtles and dolphins are caught incidentally in gillnets and use of TED in trawlnets will not substantially reduce the incidental capture. Moreover, reducing incidental capture in gillnets is more challenging. There is also resistance from fishermen on fishing ban for long duration, which affects their livelihood. Thus, in spite of the conservation measures, many species in the WLPA still continue to be exposed to human and non-human interferences. While catching and trade of the protected species have reduced fearing prosecution by the concerned authorities, interferences shown in Table 1 have the potential to reduce the effectiveness of the WLPA. These interferences also show that placing the species in the Schedules and punishing the offenders alone may not be sufficient for meeting the objectives of the WLPA.

Assessing the effectiveness of the WLPA is necessary to understand the impact of management interventions on conservation outcomes by evaluating the following three criteria: (i) the right species have been screened for protection; (ii) appropriate management processes and actions are followed; and (iii) the species protection measures have achieved their stated objectives.

To identify whether the right species are selected for protection, it is necessary to follow a screening procedure to identify the species at risk by adopting the following criteria: (i) The most important criterion is the limited geographic distribution. Narrow geographic range is one of the greatest risk factors, meaning that localized impacts can lead to extinction. Although the area of occurrence of marine species might seem large, the area they occupy within that range is usually restricted. (ii) The second important factor is the life characteristics of the species, particularly low reproductive output, and population turnover characteristics such as prolonged longevity, slow growth rate, high natural mortality rate and low production biomass that make species vulnerable to population loss. (iii) Other key features are large size at maturity and low dispersal ability. Vulnerable species possess a combination of the above characteristics that contribute to their disappearance. For example, sharks and rays combine large size with low fecundity, which make them extremely vulnerable to overexploitation. Gastropods and bivalves have no means of escape from fishing, and populations can be fished to local extinction quickly. Combined scoring for the species on these attributes is a good method to screen species for listing. The screening process will aid scientific basis of listing, inclusion of additional species, and also delisting of species that do not qualify for listing.

It is not clear what criteria were used to select the 885 species for protection in the WLPA. Sea cucumber is one example, which is placed under Schedule I and receive maximum protection like the whales and dugong. Sea cucumbers have high fecundity and are amenable to hatchery production. Controlled harvesting of the resource with proper co-management involving the users would greatly reduce illegal removal and trade on these resources. There is a need to consider these factors while listing the species. Perhaps different levels of protection may be prescribed for species placed under different schedules.

For effective conservation of species, appropriate management processes and actions should be followed. Sound planning for each taxon is the first and essential stage in supporting species conservation. It should be recognised that while species may face immediate problems of biological origin, their effective conservation needs engagement of local people, resource users, other interested individuals, communities and governments.

To assess whether the WLPA has achieved the stated objectives, we need evidences based on best scientific information to show that the marine species under protection have recovered or are recovering. In India, attempts have been made to assess the population of corals, sea cucumbers, sea horses and turtles.

However, these assessments do not provide proper estimates of the population size to demonstrate the impact of WLPA. Available data on the nesting intensity of sea turtles and sightings and stranding of whales and dolphins do not provide information on their population size. For the elasmobranchs, gastropods and bivalves proper stock assessment of the listed species has not been done. Evaluation of the performance of the WLPA has been impeded by lack of data. Moreover, these assessments are often influenced by sampling bias. Collection of data on individual management actions, outputs and outcomes of species protection, depends on reporting at the species and site level, and is therefore very resource-intensive. Conservation efforts in India are often based on the opinion of stakeholders/conservationists rather than on a critical appraisal of evidences. Any claimed conservation success (or failure) might merely be an artefact of the opinion of the stakeholders without proper collection of data. The repercussions of non-availability of relevant scientific evidence are implementation of ineffective management interventions and lack of informed policy making.

Monitoring protocols need to be developed and validated by assessing the mortality rate of adults and estimation of both population size and breeding success. After monitoring the status of the listed species, there should be a provision to delist those species that experience long-term stabilization or an increase in abundance. Delisting may include the following three steps: (1) species whose increase in population merit delisting; (2) those increasing in abundance, but not enough to warrant delisting; and (3) those whose abundance is stable.

In conclusion, the impact of WLPA on species conservation is often assumed. Rather than relying on assumptions, it is necessary to scientifically evaluate the performance of the conservation measures based on the three criteria mentioned above to understand the effectiveness of the WLPA and develop the way forward.

# Towards zero extinction: the barometer of India's marine life

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The IUCN Red List of Threatened Species™ (hereafter the 'Red List') also known as the '*barometer of life*' is the world's most widely accepted, and authoritative database providing information on the global extinction risk and conservation status of plants and animals. The Red List also provides critical information essential to guide conservation investment, efforts and actions including recovery plans for threatened and conservation-concern species; and systematic conservation planning strategies such as the identification and design of protected areas. As of November 2019, 105,700+ species have been assessed for their conservation status on the Red List, of which 28,000 (27%) are threatened with extinction, and 750 declared extinct (IUCN Red List 2019). The IUCN Red List is also a key indicator for understanding the success and progress towards global biodiversity targets such as the 'Strategic Plan for Biodiversity 2011-2020', also known as the 'Aichi Biodiversity Targets'–a set of 20 biodiversity-related targets, adopted by the parties to the Convention on Biological Diversity (CBD) in order to harmonize and synergise national and global conservation efforts against biodiversity loss.

The Indian Ocean region covers >30% of the global ocean area, supports ~30% of the world's population, harbours exceptionally high coastal and marine biodiversity, and contributes to significant quantities of harvested and farmed marine organisms. Of the 36 littoral and 11 hinterland nations that rim the Indian Ocean region, India has one of the richest coastal and marine biodiversity with more than 15,000 species (Wafar *et al.*, 2011). The rapidly expanding population and concomitant anthropogenic disturbances is however a major concern in the country, as their impacts are most evident in the coastal and marine regions, necessitating an urgent need to improve the state of knowledge on biodiversity, and develop and implement effective conservation mechanisms. Because funding is a major constraint in developing economies, achieving successful conservation require information on 'priority' species and ecosystems, based primarily on information derived from tools such as the IUCN Red List.

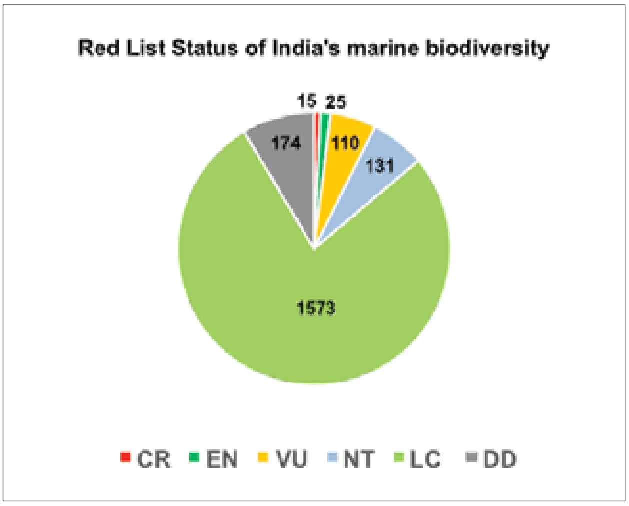
Despite the high diversity of marine taxa, only 2028 species of India's marine organisms (1991 animals and 37 plants) have been assessed for their conservation status on the IUCN Red List (i.e. <15% of the total marine biodiversity of the country; sensu Wafar *et al.* 2011). Of the species that are assessed, 150 (7%) are threatened (listed as 'Critically Endangered', 'Endangered' or 'Vulnerable'), and an additional 131 species are of conservation concern (listed as 'Near Threatened'). The small number of threatened species is unlikely a reflection of the actual state of biodiversity, but partially a result of the bias created by the selection of species assessed, and partially a result of the extremely poor state of knowledge on taxonomy and distribution of many groups. On the other hand, the large number of species listed as 'Least Concern' (1573 spp. i.e. 77% of the assessed species) is probably due to the fact that many of these are currently considered 'widely distributed', though they could in reality be species with a smaller range (and hence having a higher risk of extinction). Interestingly, many commercially important species that are harvested throughout the country are listed as 'Data Deficient', including the Indian Mackerel (*Rastrelliger kanagurta*)–

the national fish of India, the Indo-Pacific Tarpon (*Megalops cyprinoides*), Seer fish or the King Mackerel (*Scomberomorus guttatus*) and most groupers (*Epinephelus* spp.).

Some of the major marine taxonomic groups in which either partial or complete Red List assessments have taken place include seagrasses, anthozoans, echinoderms, molluscs, turtles, sharks and rays, ray-finned fishes and, whales and dolphins. Of these, ray-finned fishes comprise the largest taxonomic group whose conservation status has been assessed (1311 spp.) followed by anthozoans (331 spp.), molluscs (117 spp.), sharks and rays (117 spp.) and echinoderms (50 spp.). Groups that have the maximum number of threatened species and levels of threat are anthozoans (63 spp.; 19% threatened), sharks and rays (50 spp.; 42% threatened), and echinoderms (9 spp.; 18% threatened). While there are 18 ray-finned fishes that are listed as threatened, given the large number of species assessed (1311 spp.) percentage level of threat among this group (1%) is extremely low.

Many marine taxa including fish and invertebrates are included in the Indian Wildlife (Protection) Act, 1972 (WLPA), with several species (and groups) listed in Schedule I. But many of these taxa have either not been formally assessed in the IUCN Red List, or requires updated assessments – for example, anthozoans including black coral (Antipatharians), fire coral (Milliporans), and gastropods (except cone shells). Similar is the case with giant clams, *Tridacna maxima* and *T. squamosa*, two species of significant conservation concern in the Lakshadweep, and Andaman & Nicobar Islands, which have not been assessed since 1996, and pipefishes, a group which has been listed in the highest schedule of the WLPA, but does not contain any threatened species.

This contribution discusses the current status of India's marine biodiversity vis-à-vis IUCN Knowledge Products including the IUCN Red List of Threatened Species™, and Key Biodiversity Areas (KBAs), informs knowledge gaps in species assessments, stresses on the importance and need for greater coordination between marine species experts in India and the Species Survival Commission of the IUCN, and the development of a National Red List for marine taxa.



# Engaging communities in monitoring: the role of collective science in marine conservation

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Many ecological changes occur over periods of time longer than the lifetime of projects or even people. In the context of conservation, we often work on long-lived, late maturing plants and animals which take decades to grow and fully mature. What this means is that it may take years or decades of observation to detect a pattern or trend in populations and communities. Detecting these trends is critical to making decisions about conservation, management or sustainable resource use.

The idea of long-term ecological monitoring has gained in importance in recent years, especially in the context of climate change, with a number of national and international networks that seek to collect data on various physical (climate, soil) and biological (fauna and flora) parameters for the foreseeable future. The benefit of institutionalizing such monitoring is that it can then go beyond the timeframes of individual projects and researchers.

Many 'citizen science' initiatives also use or engage with civil society to generate long term datasets. Of course, expanding the 'personnel' involved in such data collection allows for greater spatial as well as temporal coverage. But these programmes go way beyond merely increasing the number of hands and eyes available for data collection. The objectives of citizen involvement extend to engaging communities, educating society and building a connection with nature and the environment. Hence, the motivation for the involvement of participants is more than mere data collection as these programmes can garner support of a wider swathe of the community over longer periods of time.

## Monitoring sea turtles across India

The mass nesting population of olive ridley turtles in Odisha was brought to the attention of the scientific community in 1974 by H. Robert Bustard, an FAO consultant working on a salt-water crocodile project. In the 1990s, Bivash Pandav set up monitoring camps at Gahirmatha, Devi River Mouth and Rushikulya during the course of his PhD at the Wildlife Institute of India. All these camps employed local staff to monitor the beaches, maintain the camps and to operate the boats. In Gahirmatha, the team also captured mating turtles in offshore waters to tag them, using an ingenious triangular net that they devised.

The camps at Devi and Rushikulya both led to the birth of local community based organisations. Recognising that they could continue working on sea turtles and generate funds for their work through both the forest department and other donors, many of these individuals formed their own NGOs. At Devi, the NGOs were led by Sovakar Behera (Green Life Rural Association) and Bichitrananda Biswal (Sea Turtle Action Programme) the latter barely a teenager when he first worked on sea turtles. In Rushikulya, the team that worked as Pandav's field assistants organized themselves as the Rushikulya Sea Turtle Protection Committee (RSTPC), led by the energetic Rabindranath Sahu (Rabi). In the 2000s, the team also worked as assistants for Basudev Tripathy and Suresh Kumar during their doctoral research at Rushikulya. All these NGOS comprised a diverse crew of members ranging from fishermen, agriculturalists and labourers from the coastal community who used their varied skill sets to organise themselves.

The role of communities in monitoring sea turtles in Odisha has impacts far beyond the data that they help collect. The opportunities available as employment with conservation groups and potential benefits from being raised from tourism have been seen as opportunities for alternate livelihood models.

In the Andamans, much of our knowledge of leatherback turtles comes from Satish Bhaskar's seminal surveys starting in the 1970s and extending into the 1990s. His surveys of Great Nicobar Island in the early 1990s along with other researchers established that Galathea on the southeastern coast of Great Nicobar was a major nesting beach for leatherback turtles. In 2000, a monitoring programmed was initiated at the site by the Andaman and Nicobar Islands Environmental Team (ANET). Led by Harry Andrews and researchers, the backbone of the programme were its Karen field assistants.

The Karen – a Burmese community who were in the Andamans in the 1930s and 1940s – became involved in ecological research and surveys in the late 1970s and 1980s during Bhaskar's surveys and visits by Romulus and Zai Whitaker, founders of the Madras Crocodile Bank. Following surveys of beaches in Little Andaman Islands in 2007, the Indian Institute of Science, ANET and Dakshin Foundation initiated a monitoring programme at South Bay beach in 2008, and at West Bay in 2011. These beaches had far lower levels of nesting than the beaches on Great Nicobar Island, but could potentially be used as index beaches to monitor changes in the population. As always, the Karen team played a key role in the enterprise. In fact, in the early period, there was no field researcher present at the camp, and the Karen team would manage all the data collection quite competently.

Few of the surveys over the last three decades in the Andaman Islands for sea turtles and crocodiles would have been possible, or at least as rewarding, without the Karen collaboration. In recent years, the 'Ranchi' community from Rutland have also been critical to many field projects at ANET. Their knowledge of nature and seafaring has not only been critical for the logistics of surveys and monitoring, but has enabled them to become keen observers of the biology of the fauna they have helped carry out research on. In recent years, they have become involved in in-water projects, and assisted with a range of other projects that researchers from various institutions carry out at ANET.

While it may not be possible for a single or even several research institutions to cover the entire coast, there is fortunately a great deal of public interest in sea turtle populations. In India, sea turtle conservation programmes started on the Chennai coast in the 1970s, and was initiated by volunteers and non-governmental organisations such as the Madras Snake Park and Madras Crocodile Bank. From the late 1980s onwards, many NGOs have been formed to address sea turtle conservation issues, or have incorporated sea turtles in their conservation agenda. Today, there are at least one or two NGOs in each of the mainland states that have activities related to sea turtles, ranging from monitoring nesting beaches, protecting nests in-situ, protecting nests in hatcheries, turtle related tourism and/or education and outreach about sea turtles and coastal and marine conservation.

## Monitoring tuna in the Lakshadweep

For communities, long-term monitoring programmes offer an opportunity to engage with science, which is privileged as a modern method of understanding nature and communicating about it. Since these communities often have to engage with society and government either with regard to resources they depend on, or on conservation issues in the areas they live in, such programmes allow them to gain familiarity with the language of negotiation (i.e. scientific data). For example, fishing communities can collect data on catch which may help them in negotiating management measures with the fisheries department.

The tuna fishers in the Lakshadweep were well aware of the challenges they faced (the variable catch, the decreasing size of tuna near fish aggregating devices (FADs), the lack of availability of diesel, etc). However, until they are able to show this in a 'language' that the modern State (including its scientific community) understands, i.e. data in the form of tables, figures and statistics, their knowledge provides them with little leverage.

Thus, Dakshin Foundation worked with the local communities to co-create a locally managed catch monitoring programme to improve stakeholder participation in resource monitoring and management. The programme has helped build trust and a network with fishers and facilitate collective action through meetings on co-management of resources. This initiative between conservation organizations and local community groups can also help improve communication of local needs and resource use to administrative bodies in the form of scientific evidence with the expertise of researchers.

The programme monitors trends in tuna catch as well as live bait. This data has been used to compile reports to the Administration and indicates the need for more careful monitoring of trends. It also points out the gaps in fishing infrastructure and facilities. Community support has also improved since 2015 when Dakshin began distributing 'Fish for the Future' calendars. In addition to featuring the boats that collected the 'best data', the calendars include info-graphics that provide visual representations of the data collected by the boats, and illustrations that promote sustainability and rights-based fisheries governance.

Many contemporary conservation paradigms acknowledge the need to empower local and marginal communities in their engagement with the State and dominant sections of society over the management of natural resources. In order for this to succeed, it is imperative that we explore collaborative initiatives and examine how these approaches can be applied in a manner that promotes the plurality of knowledge systems and empowerment in local communities in the context of natural resource management and conservation. Participatory community engagements in resource management are therefore geared to serve several ideals: conservation, sustainability, democratic governance and social justice.

Such long-term monitoring projects have multiple goals. They provide the data that is required for conservation strategies and management plans. While conventional citizen science programmes deal with urban or educated groups, involving the local community, especially resource dependent ones as in the Lakshadweep, expands the scope and the long-term sustainability of the project. This expands the constituency for the conservation of these species and ecosystems by garnering the support of communities. Like ecological change, social transformations can take time and collective science can make a big difference in the long run.

# A comparative analysis on the epibiotic community on pneumatophore and an artificial substratum of Ayiramthengu mangrove ecosystem of Kerala, south west coast of India

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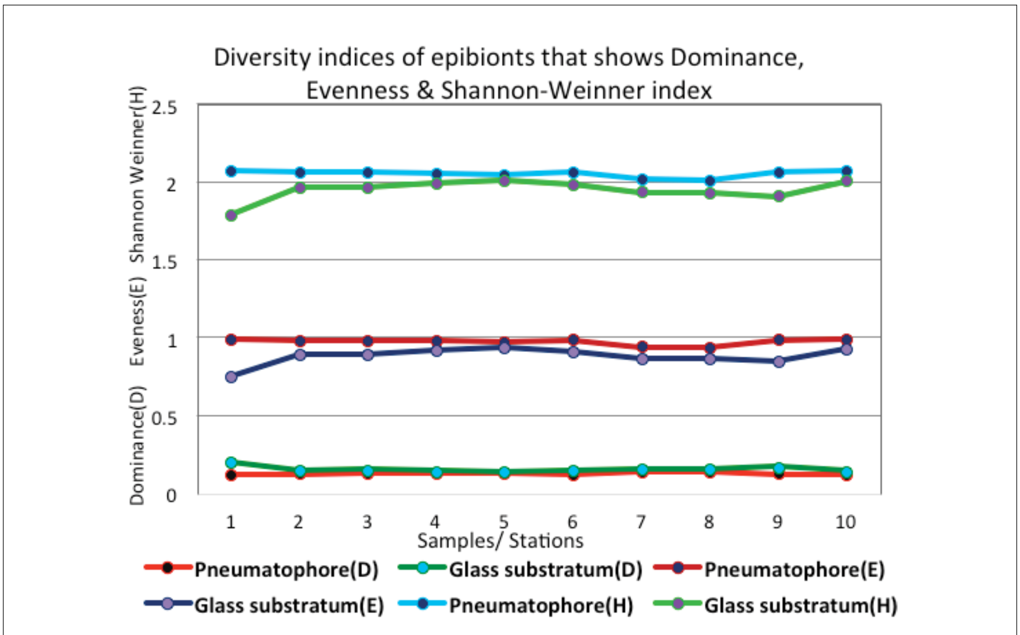
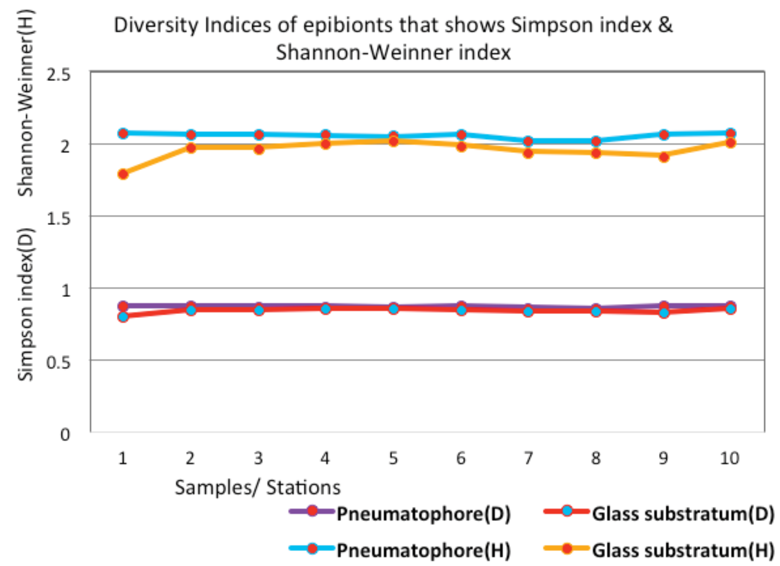
Occurrence and diversity of epibionts on Pneumatophore and an artificial substratum were evaluated for a period of 120 days at Ayiramthengu mangrove area of Kerala coast. A total of 46 genera were recorded which includes ciliates, flagellates, algae, diatoms, rotifers, nematodes and copepods. Among these forms, 14 genera were found to be specific to the pneumatophore whereas 10 genera were only confined to the artificial substratum. The major group recorded in terms of diversity and abundance was diatom which belongs to 21 genera. Among these *Cocconeis, Pleurosigma, Navicula, Nitzschia, Gyrosigma, Biddulphia, Cymbella* and *Melosira* were the common genus found on both substrata. *Coscinodiscus, Cyclotella, Campylodiscus, Bacillaria, Diploneis, Licmophora, Striatella* and *Amphora* were recorded only from pneumatophores whereas *Cyclostephanus, Puncticulata, Pinnularia, Lindavia, Encyonopsis* were found only on artificial substratum. The ciliates and rotifers were also showed a similar type of substrate specificity. Out of the total 11 Ciliates *Vorticella, Pyxicola, Vaginicola, Zoothamnium, Thuricola* and *Cothurnia* were common and found on both substrata. The ciliates *Stentor, Epistylis* and *Tetrahymina* were



recorded only from pneumatophores while *Frontonia* and *Ephelota* were found on artificial substratum. In general, the density of epibionts on pneumatophore varied from 65 to 615 no./ cm$^2$ while the density of epibionts on artificial substratum ranged from 25 to 805 no./ cm$^2$. The species diversity indices such as Shannon diversity index, species richness and evenness were varied from 2.018 to 2.077, 0.141 to 0.125 and 0.940 to 0.997, respectively in the study area and the values were always higher on pneumatophore than the artificial substratum. It was duly evident that the most dominant genera were *Vorticella* followed by *Cocconeis*, *Pleurosigma* and *Navicula*. The study revealed the fact that in terms of population density which showed not much drastic variation with regard to the two entirely different substratums occurred while the genera of taxa showed substratum preference. At the same time, building and colonization of organisms on artificial substratum occured from initial day itself and that kind of a characteristic feature which was not occurred on the pneumatophore might be reflected on the overall population density variations of epibiotic community.



# Seasonal abundance and diversity of finfishes in a tropical estuary, Karwar, southwest coast of India

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Globally estuaries are the most biologically productive and valuable ecosystem. Function and services of this ecosystem are often threatened by anthropogenic activities. Estuaries are dynamic ecosystem which is often characterised as habitats with low species diversity but high biomass. As in the marine environment, in the estuaries also the depletion of species and degraded water quality and increased species invasions has occurred due to various interventions. This loss of marine biodiversity is increasingly impairing ecosystem services. Understanding the biodiversity pattern is therefore very important when assessing the consequences of biodiversity loss to ecosystem functions and services. Hence an attempt was made to investigate the finfish diversity and seasonal abundance in Kali estuarine complex of Uttara Kannada, Karnataka.

Kali estuary (14° 50'21"N ; 74° 09'05" E) is one of the productive ecosystem of Uttara Kannada, the maritime district of Karnataka. Samples were collected from three stations in the estuary during the period April 2017 – May 2019. Identification of fishes were done following the standard identification sheets. Conventional diversity indices like H' (log 10), Shannon diversity index, Margalef's richness and J' Pielous evenness index were applied to compare the fish diversity between three stations and seasons. The data were square root transformed before computation of diversity indices, similarity and cluster analysis. The similarity in species composition was studied by calculating Bray-Curits coefficient. Cluster analysis, Bray-Curtis similarity was used to construct the dendrogram.

The fish communities in estuary tend to be dominated by a few persistent and abundant core species. Totally 24 species were recorded belonging to 19 genera and 19 families. Observation on the numerical abundance apart from Ambassidae family, Carangidae family dominated. About 12 % of the total was contributed by *Ambassis* sps followed by *Caranx ignobilis* (10%), *Liza parsia* (7%) and *Epinephelus diacanthus* (6%). The fish species included some resident species like *Etroplus suratensis*, *Scatophagus argus, Liza parsia, Sillago sihama, Ambasis* spp., and also migrants or stragglers like *E. diacanthus.*

In line with the higher number of species and abundance in Kali estuary, the Shannon diversity ($Log^{10}$) was more in station 3 (1.33) area and comparatively low in station 1 (1.18). The Margalef species richness showed clearly difference in areas registering high richness values at station 3 (4.7) and low at station 1 (3.6) which showed similar trend as it was found in diversity index pattern. Seasonal diversity study showed high values during post monsoon in station 2 and low during monsoon in station 1. The similarity in species composition and abundance among stations of Kali estuary was in the range of 62-76. The dendrogram drawn revealed clearly separated three seasons in Kali estuary with maximum similarity between pre and post monsoon. Maximum similarity in species was between station 2 and station 3 to which station 1 got linked. There is abundance of cultivable finfish seeds in the estuaries and hence judicious exploitation of the resource could be done for finfish seed for grow-out in cages.

Kali estuary is one of the hotspot regions in Western Ghats, and the biodiversity studies are of utmost importance as the estuarine system is observed to be degraded due to human interventions. Efforts are to be taken for sustainable exploitation of the resources.

# Screening of Arctic Virome – A pilot study to delineate the viral diversity

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Viruses are the most abundant and genetically diverse acellular biological entities in the oceans. Extreme environments like polar regions represent an interesting source of both DNA and RNA viruses and their identification methods are limited due to the lack of universally conserved genes. This study is focused on the diversity of viruses in water samples collected from the near glacier and transition zones of Kongsfjorden, Arctic. Viral nucleic acid extraction was done using FeCl3-based flocculation, filtration and resuspension method (FeFR) after the removal of bacteria like particles via sequential multistage pre-filtration. Presence of both DNA and RNA viruses were examined via PCR amplification using specific DNA and RNA primers, TA cloning, sequencing and sequence analysis. DNA viruses inhabiting in both zones of Kongsfjorden were represented mainly by bacteria infecting Cyaonophage and Roseophage, insect infecting Iridovirus, fish infecting Lymphocystivirus and human infecting Adenovirus. ssDNA virus and Torno virus with genome ranging from about 200 to 600 bp were detected from near glacier alone whereas algae infecting *Emiliania huxleyi* virus (EhV) and human infecting Torque virus were detected from transition zone of Kongsfjorden alone. The study exhibited limited RNA viral communities from both the zones among which 5 different RNA viruses were detected from near glacier zone of Kongsfjorden.

# A survey of macrosymbionts of Crinoid in the Lakshadweep Archipelago

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Crinoid and their macrosymbionts were observed to document their association, occurrence and abundance. Ten crinoid species belong to the four families (Colobometridae, Mariametridae, Himerometridae, Comatulidae) were observed to record the occurrence of macrosymbionts. The assemblage of macrosymbionts of crinoids includes 11 species including (two brachyuran crabs, three polychaetes, four shrimps and two galathids) of which nine species are recorded for the first time from the Lakshadweep Archipelago. Crinoid fauna of the Lakshadweep is considerably less diverse than that of similar areas like the Maldive Islands, emphasizing the need for additional research in this island group. Present paper indented to provide a comprehensive and informative report of the available data on macrosymbionts of crinoids of Lakshadweep archipelago.

# Diversity of fishes of the Family Mullidae from the coasts of Southern India, the Andamans and the Lakshadweep Islands

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Goat fishes are tropical marine fishes of the Family Mullidae. They mainly prefer sand, mud or gravel bottoms and are strongly associated with reefs. The Family Mullidae consists of six genera and 92 species worldwide, of which only three genera and 18 species are known from the Indian waters. They are recognised by bright colour with stripes and bands especially on caudal fin and presence of two unbranched chin barbels. Information on taxonomic status of Mullidae is still lacking with prominent diagnostic morphometric characters at species level. The meristic characters, such as dorsal-fin spines, pectoral-fin rays, gill rakers and lateral line scale count play a main role in species differentiation of this family. In the present study samples were collected from Andaman Islands, Lakshadweep Islands, Gulf of Mannar and Kanyakumari. In the study we were able to document nine species of goat fishes. DNA barcodes were generated for these species and this will aid in future studies and help clearing the taxonomic ambiguity pertaining to this group. The present study also reports the first occurrence of *Upeneus margarethae* from Gulf of Mannar, which will be an addition to the species diversity of Mullids from the Indian waters. The occurrence of the species suggests the extended distribution of the same in the Indian waters. Further, in depth analyses are required to resolve the complexity in identifying species belonging Mullidae. The present study would bring new insight and implication for the researchers and for conservation of the species from Indian waters.

# Valuation of economic goods and services of marine ecosystem of Karnataka

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Karnataka state is commonly known as the Mackerel coast because of the abundance of the Indian Mackerel. Fisheries sector supports a coastal population of 168000 fisher folk in around 30713 fishermen families. During the year 2018 total fish production in the state was 452056 tonnes which gives an estimate value of 36200 Crore. The state has a potential of around 3 lakhs tonnes. Karnataka coast is unique with the beaches, tourist area and rich coastal and marine biodiversity and diversified cultural and historic heritage. Karnataka state lies between 12$^{0}$ 45' 9.78" N & 18$^{0}$ 22' 53.88" to 74$^{0}$ 5' 25.09" E & 78$^{0}$ 13' 26.03" E. State has got a continental shelf of 27000 km$^2$ and exclusive economic zone of 87000 km$^2$.

The commercial fisheries revenues and costs are calculated following the World Resources Institute, Fisheries Valuation Tool (WRI, 2007). Commercial fisheries data work sheets have been developed as per the species list and landing data for the period 2010-2014 provided by FRAD and market price data provided by SEETTD of CMFRI. Standard methods and equations were followed for the valuation of ecosystem services. Value transfer methodology is important as it can be used very quickly to estimate the economic values associated with different services. The basic frame work for value transfer methodology includes five steps as described by Troy and Wilson (2006).

Present study reveals that Karnataka is highly diverse with phytoplankton (62 sp.), Seaweeds (78 sp.), zooplankton (115 sp.), Sea anemones (25 sp.), Molluscs (234 sp.), shrimps (103 sp.), marine fishes (390 sp.), birds (522 sp.), corals (89 sp.) and mangroves (14 sp.). Three species of sea turtles and three species of sea snakes were recorded from this coast. Four species of Whale usually stranded along the coast: *Balaenoptera edeni*, *Balaenoptera musculus*, *Balaenoptera physalus* and *Physeter macrocephalus* (Sperm whale). Threatened species such as *Cheilinus undulatus* (endangered), *Rhincodon typus* (Vulnerable) and *Tridacna maxima* which are protected under Wildlife Protection Act, 1972 were also recorded.

Ecosystem services provided by the marine and coastal ecosystems of Karnataka include all the four categories such as provisioning services, regulating services, cultural and recreational services and supporting services. The provisioning services such as water, food, medicines, raw materials for fuel, industries, prawn for consumption and export are provided by mangrove, lagoon, reservoirs, brackish water, salt pan, estuary, mudflat, creeks and shelf area. Major regulating services such as climate regulation, water regulation, sediment retention, waste treatment, critical habitats for breeding and larval rearing of organisms are provided by different ecosystems. Cultural and recreational services include abundance, beauty, rarity of species, habitats and providing opportunities for cultural activities, heritage, spiritual and religious activities, social interaction, recreational use, research and education. Supporting services include nutrient regeneration, habitat for migratory and resident species of fishes, birds, marine mammal and turtles. The ecosystem service values are categorized to direct use value, indirect use value, Bequest value and Option value. Not only these ecosystem service values are important, but also the different drivers which adversely affect the habitat and species.

Using the Fisheries valuation tool of WRI, the total economic values of provisioning services provided by the fisheries resources were estimated as ₹12671 (2010); ₹13118 (2011); ₹13428 (2012); ₹15437 (2013) and ₹21245 (2014). The monetary value of ecosystem services of ecosystem using value transfer technology are mangrove (8548 million), lagoon (₹95 million), reservoir (250079 million), river and canals (₹102556 million), brackish water (₹1 million), tanks and ponds (₹1.7 million), continental shelf (₹253336 million), saltpan (₹165 million), estuary (₹13187 million), mudflat (₹168 million), creeks (₹10 million) and seashore (₹47 million).

Biodiversity valuation can be used to predict the effect of direct drivers on the ecosystem quality and degradation of the development projects and can be used to propose alternative management options. Valuation enables to arrive at more informed conclusion to attain a solution to what delivers the best cost benefit ratio.

# Anthropogenic interventions in the coastal zone – a serious threat to insular ecosystem in Kadmat Island, Lakshadweep

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The many ecosystem services provided by the coastal and marine ecosystems, including the provision of livelihoods, food, recreation and socio-cultural well-being, depend on the ecosystem health. Over the years, coastal environments have been facing so many recurring natural hazards and anthropogenic interventions and results in coastal erosion and ecosystem degradation. Sandy beaches are the highly vulnerable marine ecosystem and a number of persistent drivers are negatively impacting and undermining their ability to continue to provide these services. One of the most pressing of these drivers is marine debris, which is mainly contributed by plastic. The uncontrolled developmental activities and unscientific coastal protection measures are another driving force deteriorating the health of the beaches. Such conditions are more vulnerable in the oceanic coral atolls of Lakshadweep. In the present study based on field survey at Kadmat Island (Lat. 11°10' and 11°16"N and Long. 72°45' and 72°48"E) of Laskhadweep, these vulnerable factors are recorded. This is an atoll having an area of 3.20 sq km and has a lagoon on the south west side. The prevalence of marine debris is visible in many areas, including polluted coastlines and ports. In the survey, conducted during November 2019, it was observed that the major share of plastic debris was contributed by plastic bottles (70%), followed by plastic covers (20%) and the remaining components included chappals, nets, thermocol and glass materials. In some areas of the beaches of Kadmat Island, plastic debris was burned and it is a serious environmental issue. The effects of marine debris are not only aesthetic; it has serious impacts on marine organisms, habitats, ecosystems, as well as on human health and well-being.

The second threat to coastal regions of Kadmat Island is the unscientific construction of coastal protection measures. Little work has been done to date investigating the impact of these structures on coastal vulnerability in Kadmat Island. Construction of coastal structures by putting tetrapods increased the coastal erosion instead of reducing. The hitting of waves and the churning of sediments increased the turbidity of the lagoon and negatively affected the growth of seagrasses and increased growth of filamentous algae. Losses of seagrasses have been correlated with large volumes of sediment load, originating from extensive land clearing and coastal constructions within the catchment and lagoons. The loss of seagrass ecosystem is a serious threat to the biodiversity of the lagoon, coral reef ecosystem and the existence of oceanic coral islands. Once the integrity of the meadow has been damaged (whether natural or anthropogenic), it will be exposed to increased damage by sediment re-suspension and siltation. During our survey, and based on previous studies, it is observed that such a situation is very alarming in Lakshadweep Islands, especially in Kadmat Island. Sustainable Development Goal 14 on oceans, seas and marine resources, adopted in 2015 as part of the 2030 Agenda for Sustainable Development, has a specific target focused on the prevention and reduction of marine pollution, including marine debris and maintenance of ecosystem health. In this context, this preliminary survey is a pointer towards achieving such goals.

# Bioinventorying of shallow water sponges (Porifera) from Kollam to Muttom

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Sponge resources are distributed along the south west coast of India from Enayam to Kanyakumari. They are important components of coral reefs showing ecological and commercial value. Past studies brought out information about the different species occurring in this area (Annandale, 1912; Thomas, 1979, Vinod *et al* 2014; Sunil and Thomas, 2015). Comparatively very little work has been done on the sponge fauna of southwest coast during the past and a comprehensive list of sponges is lacking. In view of the above the present work on the bioinventorying of sponges from Kollam to Muttom was taken up. An extensive survey and sampling was conducted at Kollam (Dec 2018), Kaapil (Jan 2019), Vizhinjam (Aug- Oct 2018), Kovalam (Sep 2018-Aug 2019), Perumathura (Oct-Nov 2018), Panathura (Nov,2018), Kadiapattanam (Dec 2018-Oct2019) and Muttom (Oct 2018- 2019). Sponges were collected by handpicking, snorkeling and SCUBA diving at various localities at a depth of 0-50m. The collected samples were brought to the laboratory and preserved. Sponge samples were digested separately by placing 1x1cm piece in con. $HNO_3$ and Sodium hypochlorite. The spicules were extracted, washed through alcohol series and finally preserved in 70% alcohol. They were observed at 80x magnification under Nikon SMZ 1000 microscope. Structural characteristics and length measurements of spicules were noted. The sponges were identified using Systema Porifera, a guide to classification of sponges by Hooper and Van Soest. The present study provides a comprehensive account of shallow water sponge species from Kollam to Muttom. Details regarding color, shape, morphology, texture, consistency, spicule morphology with measurement and skeletal components were collected for systematic identification of the species.

A list of sponge species hitherto recorded from the area is given. Major species reported in the present study were *Ircinia fusca* (Carter, 1880), *Gelliodes carnosa* Dendy, 1889, *Haliclona (Gellius) toxia* (Topsent, 1897), *Callyspongia (Cladochalina) diffusa* (Ridley, 1884), *Callyspongia (Cladochalina) fibrosa* (Ridley & Dendy, 1886), *Antho (Plocamia) manaarensis* (Carter, 1880), *Myxilla (Ectyomyxilla) arenaria* Dendy, 1905, *Endectyon (Endectyon) fruticosum* (Dendy, 1887), *Clathria (Thalysias) vulpina* (Lamarck, 1814), *Mycale (Carmia) mytilorum* Annandale, 1914, *Clathria (Wilsonella) foraminifera* (Burton & Rao, 1932), *Axinella donnani* (Bowerbank, 1873), *Cliona celata* Grant, 1826, *Pione vastifica* (Hancock, 1849) and *Amorphinopsis foetida* (Dendy, 1889). In this study all species of sponges reported from south west coast was reviewed and type specimens available were examined. The occurrence data and the biodiversity details of the sponges helps in conservation of the group, as the sponges are already under the schedule IV of the Wildlife (Protection) Act, 1972 with the Amendment of Wild Life Protection Amendment Act, 2002 (MoEF&CC). The presence of rocky and coral reef habitats, estuaries, lakes and muddy bottom along the south west coast provides an excellent habitat for the sponges in their larval distribution, settlement and growth. The rocky habitats and the molluscan beds provide a suitable substratum for encrusting and boring sponges of Clionidae. The natural and anthropogenic activities along the coast reduces the suitable habitat for sponge distribution and results in reduction in the distribution and diversity of sponges.

# Intertidal Sabellariids (Annelida: Polychaeta: Sabellariidae) of the west coast of India

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Sabellariids are known as honeycomb, reef builder worms and are considered as an important species of intertidal benthic communities. Present study reports the diversity of intertidal Sabellariid from the west coast of India belonging to two genera, *Neosabellaria* and *Sabellaria*. In the present study, a total of seven species were reported. Among these, one species was novel and four were first report for the Indian coasts. A total of 70 individuals belonging to these seven species were examined from different microhabitats of tidal flats and identified with the help of recent literature. This study also appended few important taxonomic characters of *Sabellaria Spinulosa*, *Sabellaria alcocki*, and *Sabellaria ranjhi* which are previously not available in the identification keys or in literature. *S. Spinulosa*, *S. chandraae*, *Sabellaria ranjhi* and *Sabellaria* sp. were distinguished by the character combination of two forms (long and short) of opercular paleae in the middle row while *Sabellaria alcocki*, *Neosabellaria cladentinus* and *Sabellaria jeramae* with combination of one form of middle paleae. Nauchal spine present in all species accept *N. cladentinus*. Appended taxonomic features like outer paleae without plume, 4-5 lateral teeth, outer most teeth are smaller, central teeth are strongly curved and 1-2 pairs of nuchal spines etc., were important taxonomic characters of the encountered novel species of this group. Description of all species are given, accompanied by detailed illustration, including drawings, photographs and table summarizing specific diagnostic characters of all these species which may act as latest identification keys for these species. The study also revealed tube morphology and distribution pattern of Sabellariid worms in the vertical zonation of the coasts surveyed. Sabellariidae species showed uniformed and clumped distributional patterns in the West coast of India. Biogenic reef of Sabellariid provides structural habitat and feeding ground to other intertidal macrofauna.

# Observations on the breeding habits of seabirds (Family Laridae) in Lakshadweep Archipelago vis a vis conservation measures

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In India, breeding of seabirds is a rarity. The only known seabird breeding sites in India are the two uninhabited islands of Lakshadweep archipelago, the Burnt Island (Vengurla Rocks) off Maharashtra coast and the Adams Bridge between India and Sri Lanka. Among these, the two oceanic atolls of Lakshadweep supports far more number of birds than the other two. Observations and studies since 1800s have shown that three species of the Family Laridae (Sooty tern, *Onychoprion fuscatus*; Great Crested tern, *Thalasseus bergii* and Brown Noddy tern, *Anous stolidus*) occupy these islands for breeding. Pitti Island (10.775°N 72.535°E), located at the centre of a triangle formed by inhabited islands of Kavaratti, Agatti and Amini is particularly important as breeding grounds of these terns. Results of preliminary investigations on the breeding habits and diversity of three species of terns with respect to conservation measures are presented in this paper.

We carried out three bird monitoring single day surveys in Pitti Island during the months of January, March and October 2019. Counts of birds belonging to the three species of Laridae were taken in the morning hours (between 7 AM and 10 AM). We relied on high quality photographs for counting the birds, as it gave the most accurate number of birds in the islands. Significant variations in number of the life cycle stages of the three species were observed in the three months. Eggs in January belonged to Sooty terns while those of both Sooty and Brown Noddy terns were noted in March. Observation in early October revealed the presence of Brown Noddy hatchlings and very few juveniles of Great Crested terns and Sooty terns. Birds with prey such as flying fish (Family: Exocoetidae) were also observed. Observations show that Sooty terns and Brown Noddy terns both resort to Pitti Island for egg laying, but except for few juveniles, eggs or hatchlings of Great Crested terns were not found in any of the three surveys. Still they formed the largest flock in March with around 505 individuals, all non-breeding adults, counted in a photograph (Moore, 2012) of a single flock. This shows light into the fact that Pitti Island is not only used for breeding, but also as wintering grounds of terns. It was noticed that human poaching of eggs are a major threat to these birds. Fishermen from the nearby Islands of Kavaratti, Agatti and Amini regularly enter the Island and collect all the eggs except in the monsoon months when the waves restrict the entry. The regular interference of people in a breeding colony also pressurizes the birds to abandon the incubating eggs. This will lead to the non-hatching of a portion of total eggs laid. The most impacted one was found to be the Sooty tern which breeds during the fair weather season, whereas monsoon that prevents human access to the island protects the eggs of Brown Noddy terns to a great extent.

Seabird research in India is still in its childhood. Most of the studies were confined to the monitoring the diversity and number of migratory seabirds in the coastal and continental shelf waters around India. Given the importance of seabirds in assessing the health of ocean ecosystems, overlooking their ecology in extremely small sandbanks surrounded by human inhabited islands, as in the case in Lakshadweep, is a major drawback in implementing effective conservation measures. Lack of easy access and remoteness of the island are the main reasons that keep it outside the purview of effective scientific monitoring and conservation.

# Mudskippers diversity along the selective mudflats of mangroves of east coast of India

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Mudskippers (Gobiidae: Oxudercinae) a highly evolved group of fishes, are distributed exclusively in the mudflat region of estuary and mangroves of Indo- West Pacific. 34 species of mudskippers were recorded worldwide. The diversity and abundance of mudskippers in the mudflats indicate the healthy status of mangrove environment. They execute full-time essential activities like feeding, constructing burrows, territoriality, parental care and revealing skipping behavior etc. during low tides. The distributional record of Indian mudskippers are rare and hence the present study was aimed to study the species diversity and assemblage of mudskippers in the mudflats environments of five major mangroves of east coast of India especially a selective part for sampling along the Sundarbans, Bhitarkanika, Coringa, Pichavaram and Muthupettai. The samples of mudskippers were collected in the mudflats by scoop net and handpicking methods. The mudskipper specimens were identified and preserved. Diversity indices were calculated for statistical analysis. The results revealed that, of the 17 species recorded, the genus *Periophthalmus* was found to be the dominant group with 6 species while the genus *Boleophthalmus, Scartelaos* and *Parapocryptes,* were the next dominant group with 2 species each. The genera *Apocryptes, Apocryptodon, Oxuderces, Pseudapocryptes* and *Periophthalmodon* were found to have only one species each. It could be observed that the mudskipper *B. boddarti* was the single most dominant and abundant species, which was uniformly distributed in all the stations. Among the five stations for sampling of fishes, the station (1) (Sundarbans) dominated with 17 species of mudskippers followed by station 2 (Bhitarkanika) (9 species), station 4 (Pichavaram) (7 species), station 5 (Muthupettai) (6 species) and station 3 (Coringa) (5 species). The species richness (Margalef index (d) ) ranged between 7.966 (station 1) and 14.826 (station 3). Similarly, the species evenness (Shannon evenness index) was varied from 0.765 (station 5) to 0.974 (station 2). The species diversity index (Shannon diversity index) varied from 0.568 (station 3) to 1.146 (station 1). Thus monitoring of species diversity plays a vital role in an ecosystem to understand the healthy and endemic nature of such mudskippers for their potential use as an ecological indicator in the mudflats of estuary and mangroves.

# Diversity and morphometric analysis of Family Cerithiidae (Gastropoda: Mollusca) from south Saurashtra Coastline, Gujarat, India

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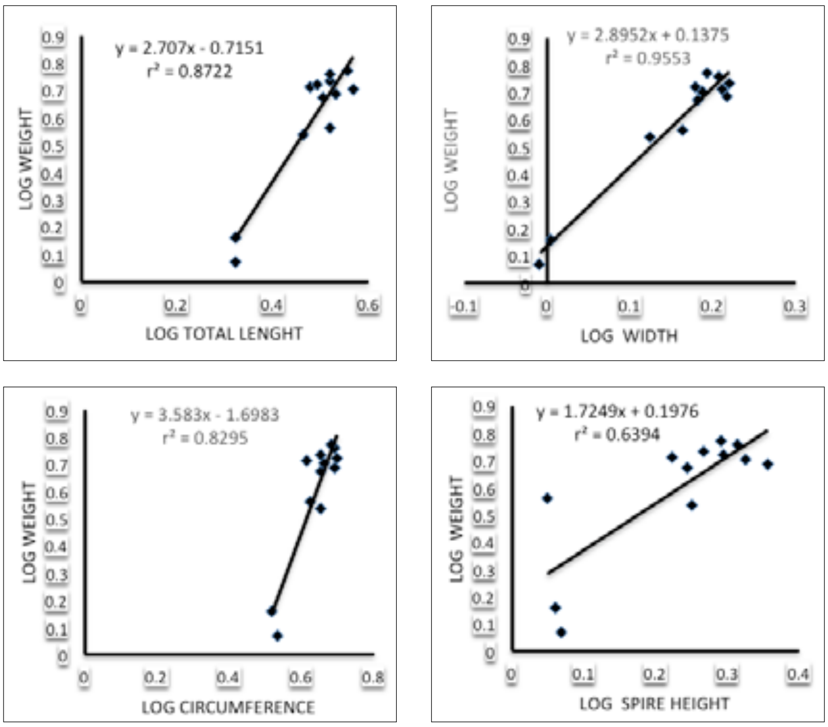
The present communication revolves around the diversity and the morphometric characters of gastropod mollusc species of family Cerithiidae from rocky intertidal zones of south Saurashtra coastline, Gujarat. The selected coastal areas have been surveyed on a monthly basis and the voucher specimen of the species of Cerithiidae family was collected for identification as well as various morphometric analyses. Measurement of Weight with different measures such as total length, width, penultimate whorl height, body whorl height, spire height, aperture width and aperture height were estimated by using the expression of power law equation. Results of the present study showed the diversity of family Cerithiidae and their distribution along the vertical intertidal zones. Present study also revealed the efficacy of shell morphometric characters for the purpose of understanding the growth performance and species identification of the family Cerithiidae. In this line, relative growth dynamics have also been discussed by using various morphometric features of the gastropod shells. Glimps of graphs are given below for the different relative measurements.




Allometric relationship of weight with other morphometric parameters of Cerithium caeruleum

# Diversity of zooplankton along the northern part of Vembanad Lake

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Zooplankters are highly sensitive to changes in aquatic ecosystems and the effects of environmental disturbances can be detected through changes in species composition, abundance and body size distribution. They are good indicators of change in nutrient pollution over time because they respond quickly to changes in nutrient input to the waterbody.

For the present study, zooplankton samples were collected monthly from six stations namely Cochin bar mouth, Mulavukad, Kadamakkudy, Kadakkara, Azhikode bar mouth and Kottappuram, along the Kollam –Kottappuram water way (National Water Way 3) on the northern part of Vembanad Lake during the period from October 2018 to September 2019. The samples were analysed both qualitatively and quantitatively by adopting standard methods.

24 groups of zooplankton were recorded from the study area. Qualitative and quantitative distribution of these groups in the six stations is presented. Out of the 24 zooplankton groups, a maximum of 19 groups were recorded from station 1 (Cochin bar mouth) and a minimum of 9 groups from station 6 (Kottappuram). Station-wise studies indicated that the average zooplankton density was maximum at station 2 (4934 per 100 $m^3$) and minimum at station 5 (1663 per 100 $m^3$). Among the different groups of zooplankton in the study area, a maximum of 79 % composed of copepods, 14 % by rotifers and rest of them contributed only less than 2 %. Month-wise analysis indicated the maximum density during the month of September and minimum during January. Biodiversity analysis was carried out by Primer v.6 software and the results are described and discussed.

# Effect of coastal upwelling in the phytoplankton community structure in the off-Kochi waters during winter monsoon and spring inter monsoon of south eastern Arabian Sea

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In the South Eastern Arabian Sea, strengthening of wind enhances upwelling, which results in lowering of surface temperature, high concentration of nutrients and high primary production. In the present study, water samples were collected on monthly basis from coastal waters Off-Kochi (upto 100 m) and were analysed for vertical distribution of physical parameters as well as inorganic nutrients. Correspondingly, phytoplankton samples were analysed to study the phytoplankton community structure of the winter monsoon (WM) and spring inter monsoon (SIM). Concentration range of ammonium, nitrate, nitrite, phosphate, silicate and DO were 0.02-0.80 μM, 0.5-6.71 μM, 0.1-0.69 μM, 0.1-0.96 μM, 0.5-13.54 μM and 86.20 to 243.94 μM respectively. In December, stratification was less (high saline cold water at 100 m depth) and the near shore region receives dense accumulation of silicate which indicated that the area acquired large river runoff. Abundance of diatom (62%) in this region showed positive correlation with silicate. During WM, water up to 50 m were characterised by oligotrophic condition (low nutrients) with low primary productivity and low abundance of phytoplankton. There occurred a pivotal increase of phytoplankton abundance during SIM. A recognizable increase of cyanobacteria (*Trichodesmium erythraeum*) was observed in the deeper layers (up to 50 m depth) in the offshore region, high nitrate concentration was recorded in this period and strong nitrification occurred at deeper layers of the offshore region. *Coscinodiscus* sp. and *Cyclotella* sp. were the major species of diatoms where as *Ceratium* spp. and *Ornithocercus* sp. were the major dinoflagellates. While comparing near shore to offshore, the phytoplankton abundance during WM did not show any large significant trend, but during SIM, there was an increasing trend in phytoplankton abundance which indicated the progression of upwelling. During upwelling period, cool, high saline nutrient rich water (low-$O_2$~80–85μM) shoaled progressively towards mid-shelf region which enhanced the growth of phytoplankton.

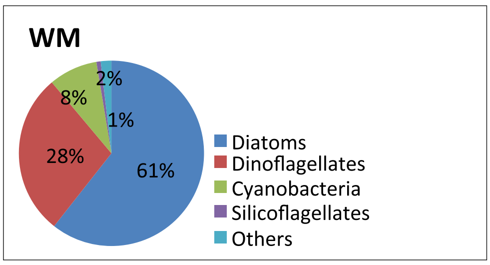


Fig. 1. Phytoplankton community structure during winter monsoon\

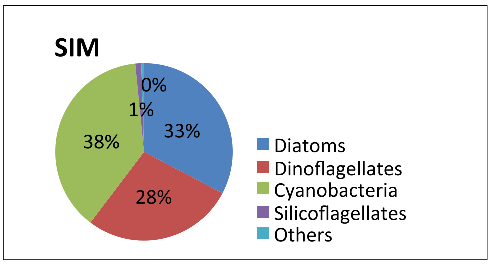


Fig. 2. Phytoplankton community structure during spring inter monsoon

# Diversity of snappers (Family Lutjanidae) in the Arabian Sea

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Fishes of the family Lutjanidae collectively known as snappers comprise 17 genera and 105 species, mainly confined to tropical and subtropical marine waters, with few also entering estuaries. *Lutjanus* Bloch 1790 is the largest genus with 70 species, including at least 43 species from the Indo-West Pacific region. Though the taxonomy and systematics of *Lutjanus* has been the focus of much research in the tropical Indo-Pacific, limited work has been done in the Indian waters, especially in the Laccadive Sea and the archipelago. This study was carried out to determine the diversity of members of the genus *Lutjanus* from the South West coast of India and the Laccadive archipelago using conventional morphology and biometrics. A total of eight species, *Lutjanus kasmira*, *L. gibbus*, *L. fulvus*, *L. bohar*, *L. lutjanus*, *L. argentimaculatus*, *L. fulviflamma* and *L. johnii* were recorded from various locations with *L. kasmira* and *L. gibbus* being the most widely distributed and abundant. Several species including *L. fulvus*, *L. lutjanus*, *L. fulviflamma* and *L. johnii* were limited in their distribution and recorded from only one island in the Laccadive archipelago. On the other hand, *L. kasmira* and *L. gibbus* are widespread in the Laccadive archipelago. Further studies using mitochondrial and nuclear genes, and osteology should be carried out to improve our understanding of the diversity and distribution of *Lutjanus* species from the Arabian Sea, and inform future priorities for conservation and management.

# Spatio-temporal variation in the phytoplankton diversity and abundance in the Devgad Island, Karwar, eastern Arabian Sea, India

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Diversity and temporal variation in phytoplankton abundance in the Oyster rock or Devgad or Devadgudda Island were studied from March 2015 to February 2016. Standard phytoplankton net with flowmeter was used for phytoplankton sampling and collection. Sampling was done fortnightly in small FRP boat of length overall (OAL) 6m with phytoplankton net towing speed of 2knots/hr for 10 minutes. Concentrated 100 ml phytoplankton were collected from the cod-end of the net and preserved in Lugol's solution for further analysis. Quantitative analysis of phytoplankton was done using Sedgewick Rafter. In total, 51 species of phytoplankton from 39 genera, 30 families, 25 orders, 6 class were identified. The class that contributed maximum was Dinophyceae (27.45%), Mediophyceae (27.45%), Bacillariophyceae (23.53%) and Coscinodiscophyceae (15.68%). The most abundant species were *Coscinodiscus granii* (13.31%), followed by *Thalassionema nitzschioides* (10.24%), *Trichodesmium* sp. (7.5%), *Thalassiothrix longissimi* (4.06%), *Pleurosigma elongatum* (3.86%), *Lampriscus shadboltianum* (3.73%), *Eucampia zodiacus* (3.63%), *Thalassiosira eccentric* (3.41%), *Ceratium massiliense* (3.31%), *Palmeria hardmaniana* (3.29%), *Chaetoceros diversus* (3.18%) and *Dinophysis miles* (3.01%). Seasonal Bray–Curtis similarity coefficient and dendrogram plot for phytoplankton showed high similarity (92.77%) between winter (January and February) and monsoon (August and September) in species composition and low similarity (82.27%) was found between post-monsoon (October to December) and pre-monsoon (March to May). The season-wise species richness index (D) for phytoplankton ranged between 9.87 and 11.08. The maximum was observed during monsoon and the minimum value was observed during pre-monsoon. The species diversity index (H) ranged between 3.71 and 3.90. The high species diversity recorded during post-monsoon and minimum species diversity was recorded in the pre-monsoon. Devgad Island ecosystem found to be healthier as Shannon-Weaver diversity index value is more than 3 in all the four seasons indicating that water quality is good throughout the study period. There is no significant difference between seasons in species evenness (J) as the value almost between 0.98 and 0.99. The season-wise cumulative dominance plot reveals that post-monsoon found to have low dominance in species distribution and observed high dominance in species contribution in pre-monsoon season. Similarity percentages (SIMPER) in the abundance of phytoplankton within the season were found to be 87.67%. This study forms a baseline database on phytoplankton diversity in the Devgad island ecosystem.

# Intertidal Echinodermata of the Diu Island, India

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Echinodermata are highly diverse in most of the marine habitats such as intertidal belt to great depths. The present study was undertaken to understand the diversity, distribution and ecological status of Echinodermata from two distinct habitats viz., rocky and rocky-sandy coasts, available at the Diu Island, Diu, India. The Union Territory of Diu (20° 42' N, 70° 53"E) is an island, located on the outer rim of the Gulf of Khambhat, off Arabian Sea. Entire Diu coast was extensively surveyed on monthly basis from October-2017 to June-2018. Among the coasts, Nagoa coast and Gangeshwar coast were selected as sampling sites for ecological studies based on their coast characteristics, tidal exposure and ecological habitats. Different species of phylum Echinodermata were observed at the rocky and sandy portions of the surveyed coastline. From the present study, sixteen species of Echinodermata were noted from the intertidal zones of the Diu coasts. Diversity indices of the observed species revealed that *Amphipholis squamata* and *Ophiactics savignyi* were more dominant with high richness in the selected sites. Result of the biodiversity indices indicated that Nagoa coast and Gangeshwar coast had only 9.09 % similarity. Six Echinodermata species were studied for their population status. The study also revealed that most of the Echinodermata species preferred microhabitat like as rock pools and puddles, sandy shallow pool, zoanthid colonies, rock crevices and underneath of the milliolite rocks. All ophiuroids species was observed only in the middle littoral zone of the sampling sites. This possibly indicated the uneven distribution of this Echinodermata in the selected coastline which effect their habitat pattern. *Amphipholis squamata*, *Ophiocomella sexradia*, *ophiuroidea* sp.1 and *ophiuroidea* sp.2 showed significant spatial variations in all ecological attributes like density, abundance and frequency at Gangeshwar coast. While, *Ophiactics savignyi* and *Ophiuroidea* sp.3 exhibited significant spatial variation in density, abundance and frequency at both the coasts. All Ophiuroidea species showed no significant temporal variation at any of the sampling site of Diu.

# Distribution of triggerfish- a keystone species in the coral reefs of Lakshadweep Archipelago, Central Indian Ocean

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Triggerfishes are seen in most of the tropical and subtropical seas of the world and serve as one of the most important predators in the coral reefs. They contribute an essential party in the dispersion of some predominant coral species. The present study reveals the distribution of 16 species of Triggerfish, belongs to 8 genera in various atolls of Lakshadweep archipelago. A total of 273 belt transects were surveyed in the atolls, and the study was carried out from October 2016 to December 2018. Occurrence and abundance of Triggerfish at depths ranging from 1m to 30m were recorded with the help of snorkelling and SCUBA diving with a simultaneous recording by photography. The species-rich genera were *Balistapus, Rhinecanthus*, and *Sufflamen* (represented by three species each), followed by the genera *Pseudobalistes* and *Melichthys*, which are represented by two species each. Single species each could be reported from the genera *Canthidermis, Odonus,* and *Abalistes*. *Odonus niger* (Rüppell, 1836) was found to be the predominant species across the atolls. Distribution of *Pseudobalistes fuscus* (Bloch & Schneider, 1801) is restricted to Kadmat atoll. In comparison to the other species, the occurrence of Triggerfish, *Balistoides conspicillum* (Bloch & Schneider, 1801) is rather spare. In the present study, we provided an updated checklist of the triggerfishes from the atolls of Lakshadweep archipelago and the conservation status of the species. The paper also highlights the impact of natural and anthropogenic disturbances on triggerfish resources.

# Diversity and variations in the radular morphology of intertidal Gastropoda from Veraval coast, Gujarat, India

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Gastropods are a highly divers class of molluscs, commonly known as snail and slugs. In the present study, diversity assessment has been done during May to October 2019 in rocky intertidal area near Veraval of the south Saurashtra coastline. Quadrat and direct handpicking methods were used in this survey. In this study, a total of 55 individuals of 30 different species belonging to ten families (Conidae, Turbinidae, Muricidae, Neritidae, Cerethidae, Trochidae, Littorinidae, Nacellidae, Pisaniidae and Mitridae) were examined. Shell morphology and radular morphology were key characters for the identification of Gastropoda species. The radula is a specific character and part of the digestive system of majority of the molluscs. The shape and structure of the radular teeth are unique to species or genus level. Four type of radula (taxoglossan, rhipidoglossan, docoglossan and taenioglaossan) were observed under microscope in the specimen studied. Outer lip, mouth aperture, body whorl, operculum and apex of shell were the few distinguished characters which were used to examine shell morphology. It was evident that the operculum was absent in families Conidae and Nacellidae; Turbinidae has a strong and thick operculum; Muricidae has frequently bearing spines, and blade like processes and Neritidae has calcareous 'D' shaped operculum. It was also observed that the Gastropoda were mostly clumped and randomly distributed in upper and middle rocky intertidal zones of the Saurashtra coast.

# Species diversity of elasmobranchs of the fishery landings at Digha Mohana international fish market, West Bengal

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Elasmobranch research from northern Bay of Bengal of India is limited. Digha Mohana International fish market in West Bengal is one of the major and largest marine fish landing centres in the region. Elasmobranchs constitute a regular part of bycatch landing in the region mainly dominated by trawls.

Fish landing survey was conducted at Digha Mohana fish landing centre during the fishing season, i.e., June 2018 to March 2019. This study reports 24 Elasmobranchs (9 sharks and 15 batoids) that comprises of 5 orders, 11 families and 19 genera. Common species landed accounts for 15 species (62.5%) followed by 9 species (37.5%) which were rarely observed. Out of 24 species documented, 11 (45.83%) are classified as threatened: 3 (12.50%) are assessed as Critically Endangered (CR), 2 (8.33%) Endangered (EN) and 6 (25.00%) Vulnerable (VU). Further 7 species (29.17%) are categorised as Near Threatened (NT). All sharks and batoid species were victim to bycatch in bottom trawls. Smaller sized shark species (*Scoliodon laticaudus*) and rays (*Brevitrygon imbricata, Gymnura poecilura* and *Pateobatis bleekeri*) were often caught in gill nets and beach seine nets respectively.

We have documented 9 species which were not reported in previous studies from the region. These includes: *Pastinachus gracilicaudus, Pateobatis jenkinsii, Aetobatus ocellatus, Rhinoptera jayakari, Rhinoptera javanica, Mobula mobular, Alopias superciliosus, Carcharhinus leucas* and *Carcharhinus macloti*. Nevertheless, the previously available checklists from the Digha coast are out of date an updated checklist is presented for West Bengal.

# Impact of the gelatinous Zooplankton on the planktonic standing stock of the Cochin Estuary

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Increasing incidences of jelly fish swarms and the threats imposed by them on the fishery potential and ecosystem services of the marine and estuarine ecosystems is a major topic of research globally. Jellyfishes, the hydrozoan, scyphozoan and cubozoan representatives of phylum Cnidaria forms a major constituent of the zooplankton community of the aquatic ecosystems. Cochin estuary (CE), the largest estuarine ecosystem along southwest coast of India is remarkable for its rich biodiversity and fishery potential. However, in the recent years, increasing frequency on the occurrence of jellyfish swarms have been reported from the CE. Hence, the present study is attempted to assess the impact of the rising jellyfish population on the planktonic standing stock, which forms the base of the aquatic food chain. Sampling was conducted twice, during the early and late phases of the pre-monsoon period (March and May), when high saline condition prevails throughout the estuary. Estimation of hydrographical variables, size-fractionated phytoplankton biomass and zooplankton distribution was carried out at 6 locations along the salinity gradient of the estuary.

Jelly fish abundance was high during May compared to March. During May, the Scyphozoan medusa, *Acromitus flagellates* (Fig.1) was observed throughout the sampling locations. Among the hydrozoan jellyfishes, *Blackfordia virginica* (Fig.2) formed the dominant species in the CE. Dissolved oxygen, the total inorganic nitrate, chlorophyll *a*, fractionated phytoplankton biomass and suspended particulate matter exhibited conspicuous variability between the two periods. Macro and micro phytoplankton biomass was relatively higher during May compared to March whereas a reverse trend

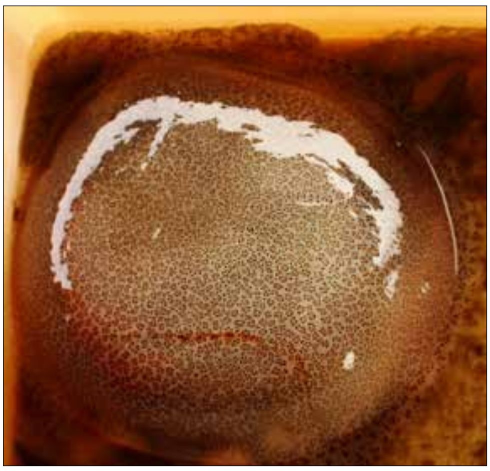

Fig 1. *Acromitus flagellatus*

Fig 2. *Blackfordia virginica*

was observed in the case of the nano and picophytoplankton community. A conspicuous decline was evident in the zooplankton abundance with the increase in the jellyfish abundance. Among the mesozooplantkon community, a significant drop was noticed in the abundance of Copepoda, Decapod larvae, Fish eggs and Fish larvae concurrent to the higher jellyfish abundances.

Jellyfish abundance though exerted a negative impact on the zooplankton community, the intermediary conduits in the estuarine trophic chain, they had a positive influence on the macro and micro size-fractions of the phytoplankton community (Fig. 3). The study thus indicates a 'trophic cascade' in the CE food web with the increase in jellyfish abundances. The increasing predation pressure exerted by the rising jelly fish population on the zooplankton community indirectly lead to the blooming of larger phytoplankton cells having a deleterious effect on the water quality of the CE. The study also indicates the detrimental effect of the gelatinous organisms on the fishery potential of the estuarine ecosystem through their grazing pressure on the ichthyoplankton, decapod larvae and on Copepoda, the primary diet component of the many early fish larval stages.

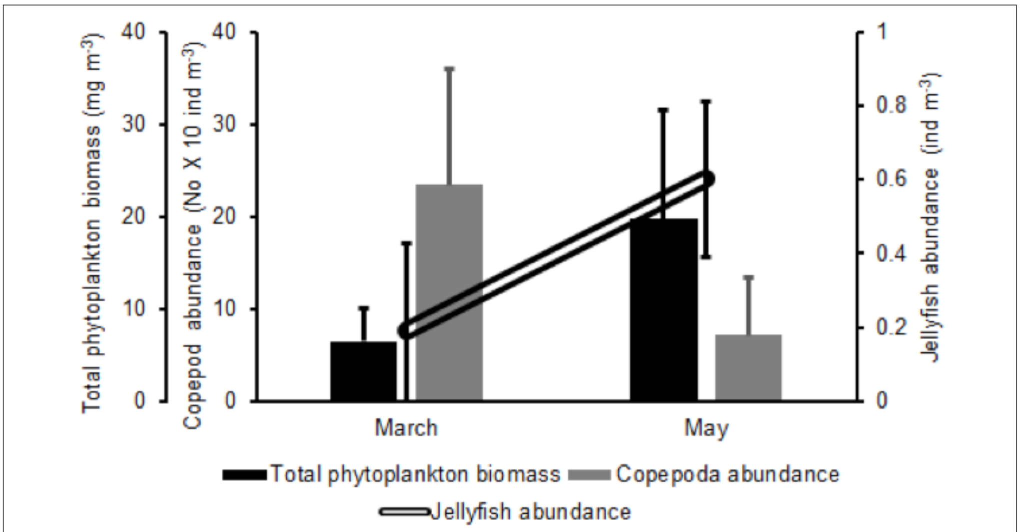


Fig. 3. The variation in the total phytoplankton biomass (mg $m^{-3}$), Copepoda abundance (No ×10 $m^{-3}$) and jellyfish abundance (ind $m^{-3}$) between the sampling periods

# Mullet mysteries: reflection of current genetic diversity of family Mugilidae in India

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Mullets, fishes under the family Mugilidae currently comprises 78 valid species under 27 genera occurring in marine and inland waters of the tropics and subtropics, where they are popular in capture fisheries, aquaculture and also intricately connected to cultural values in several nations (Crosetti 2015). Mullets also make significant contributions to the functioning of estuarine and coastal processes by directly using organic particulate matter (including detritus) and primary production, and also accelerating the turnover of microphytobenthos (Lefeuvre *et al.,* 1999). Though the family currently comprises close to 80 valid species under 27 genera (Fricke *et al*., 2019; Britzke *et al*., 2019), more than 300 nominal names are known to exist (Fricke *et al*., 2019). In India, 20 species are currently recognized, but their taxonomy is in flux, hindered by apparent difficulties in identification and species delimitation.

In this paper, we provide an overview of the diversity and distribution of family Mugilidae in the inland and marine waters of India (including the Laccadive archipelago) India, through a phylogenetic analysis of their mitochondrial cox1 gene; assess the taxonomic accuracy and reliability of species identification associated with the DNA barcode library available in GenBank and BOLD; and suggest 'species groups' which need to be investigated in greater detail so as to improve our understanding of this family. A dataset comprising of 195 sequences including 44 newly generated sequences and 151 published in GenBank formed the basis of our analysis. Species delimitation analysis revealed that at least 23 species under eight genera (*Planiliza*, *Ellochelon*, *Osteomugil*, *Crenimugil*, *Mugil*, *Minimugil*, *Rhinomugil* and *Plicomugil*) are present in India, suggesting that the currently known diversity is underestimated. This includes at least one new species of *Osteomugil* in coastal waters and estuaries of southern India. Around 46 sequences of mullets currently available in GenBank are probable misidentifications, and need to be used with caution. A major species currently misidentified in Indian literature is *Planiliza macrolepis*, which is restricted to South Africa and adjoining regions. The current state of diversity and distribution of Mullets in India is discussed.

# Diversity and ecology of Zooplankton in a prawn culture farm at Edavanakad, Cochin

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Zooplankton form an important link in the food web of any aquatic ecosystem and the abundance of zooplankters are influenced by various physical, chemical and biological factors. The present study was conducted in a prawn culture farm and adjoining canal at Edavanakad which is bounded by Arabian Sea on the west and Cochin backwaters on the other sides. This is the largest prawn culture farm in Vypin Island. For this study, five stations were fixed inside the culture pond; while two stations were selected from the outer part of culture pond in the canal which joins the culture pond with the Vembanad Lake.

Zooplankton and water samples were collected from the seven stations on fortnightly intervals during Feb- May, 2018. Zooplankton samples were analysed qualitatively and quantitatively by adopting standard methods. Data on fishery resources in the prawn culture farm was also collected. Water samples were analysed for different physico-chemical parameters such as air temperature, water temperature, salinity, pH, dissolved oxygen and nutrients like phosphate, nitrate and silicate using standard methods.

A total of 18 groups of zooplankton were identified from the seven stations. Zooplankton density was maximum in the first station (1024 Nos./$m^3$) and the least abundance was recorded from the seventh station (294 Nos./$m^3$). Copepods were the major group in most of the stations and the concentration varied from 124 Nos./$m^3$ (fourth and sixth station) to 1353 Nos./$m^3$ (first station). In the study area, copepods contributed the maximum (54%) to the total zooplankton abundance followed by Amphipods (15%); Mysids (10%) and the other groups contributed only less than 10% each. The month wise analysis of zooplankton revealed that the number of species was maximum during February and minimum during May. The maximum density was observed in March (6769 no's/$m^3$) and February reported the least density (4205 Nos./$m^3$). The stations differ in the concentration of dissolved oxygen and nutrient profile. The distribution and abundance of zooplankton both inside and outside the farm, ecology and fishery of the study area are described. Diversity analysis of zooplankton was done using *PRIMER* v. 6 software and the results are presented and discussed.

# Reviewing the applications of various satellite data for the classification of Indian Mangroves

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Taxonomic identification of species in mangroves has become a controversial topic over many years as there are many similar mangroves with identical morphological characteristics but proven as different species with molecular identification tools. Advancement of satellite remote sensing techniques can be used to resolve these kinds of issues in modern science. The European satellite sentinel 2A with a resolution of 10 meter is the advanced and latest satellite that provides data for studying plants and its taxonomy in detail. The hyperspectral images from Sentinel 2A can be used to identify the plants up to its genus level. The data is freely available in the USGS website and can be downloaded free of cost for research purposes. This approach has hitherto been unattempted to study Indian mangroves, and would be a pioneer study in India. Each genus of mangrove like *Rhizophora, Avicennia* etc have specific remote sensing reflectance that could be used as signature wavelengths to identify the genera. Mangroves in India range from threatened to least concern category in the Red list. Therefore precise identification and mapping is necessary for conservation purposes. Callous felling of mangroves for aquaculture and construction purposes destroys these rare mangroves also. Therefore, accurate mapping of different species of mangroves is the need of the hour in Indian scenario.

# First detailed report of Banded driftfish *Psenes arafurensis* (Gunther, 1889) from the Arabian Sea

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Drift fishes belonging to the family Nomeidae are known to be distributed circumtropically. Among them four species of the genus Psenes, namely *P. indicus, P. whiteleggii, P. arafurensis* and *P. cyanophrys* are reported from the Indian Ocean. A specimen of *Psenes* sp. measured 26.4 cm in total length (TL) weighing 286.5 g was collected from a multiday trawler, operated off the southwest coast of India and landed at Puthiyappa Fisheries Harbour, Calicut, Kerala on 14-09-2018. The species was identified as *Psenes arafurensis* based on morphometric and meristic characteristics using FAO species identification sheets. DNA barcoding which is a validated tool for species identification was also employed as a supplemental identification method. Genomic DNA was isolated from the tissue stored in 90% ethanol using phenol-chloroform method. Amplification of partial sequences of COI gene was carried out using the primer set FishF2/ FishR2 (Ward *et al*., 2005). The COI sequence from the present specimen (Accession no.: MN746281) exhibited an identity of 99.8% to *Psenes arafurensis* sequences available in GenBank. The earlier report on the species from Arabian Sea was in 1939 by Norman without a morphological description of the species. This is the first record of the species from the west coast of India.

# Biodiversity value of the ecosystem services in the coastal and marine regions of Tamil Nadu

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Tamil Nadu, descending to the tip of the peninsular India, has the unique advantage of facing three major seas, the Arabian Sea, Indian Ocean and the Bay of Bengal, and having the benefit at its disposal of both the monsoons, the South West and the North East. The state has a long and glorious tradition of maritime activity including fishing; pearls and chanks were exported since time immemorial to many Mediterranean countries, such as Rome, Greece and Egypt. Tamil Nadu has 13 coastal districts namely, Thiruvallur, Chennai, Kanchipuram, Villupuram, Cuddalore, Nagapattinam, Thiruvarur, Thanjavur, Pudukottai, Ramanathapuram, Tuticorin, Tirunelveli and Kanyakumari.

Data regarding biodiversity valuation such as population details, number of fishing crafts and gears, area of different coastal ecosystems, fish catch details and ecosystem services provided by different coastal and marine habitats for different coastal districts along Andhra Pradesh coast were collected. The commercial fisheries revenues and costs are calculated following the World Resources Institute Fisheries Valuation Tool (WRI, 2007). Commercial fisheries data work sheets are developed as per the species list and landing data for the period 2010-2014 provided by FRAD and market price data provided by SEETD of CMFRI. Value transfer methodology is important as it can be used very quickly to estimate the economic values associated with different services. The basic frame work for value transfer methodology includes five steps as described by Troy and Wilson (2006).

Silver belly species are abundant along the Tamil Nadu coast and utilized as fresh and dried. Commercially important gastropods are *Turbinella pyrum, Turbo mormaratus, Trochus niloticus, Lambis chiragra* and *L. lambis*. Bivalves form important provisioning service and species such as *Villorita cyprinoides, Paphia malabarica, Meretrix casta, Marcia opima, Pinctada fucata, P. indica Crassostrea madrasensis* and *Saccostrea cuccullata* exploited mainly from Gulf of Mannar. Ray fishery of Tamil Nadu is supported by *Dayatis bleekeri, D. urank, D. sephen, Aetobatus narinari, Rhinoptera javanica, Gymnura poecilura, Mobula diabolus* and *Manta birostris*. Seer fishery is supported by *Scomberomorus commerson, S. gutttus, Acanthocybium solandri* and considered to be one of the high value fishes.

Fisheries profile of Tamil Nadu shows that there are 573 marine fishing villages wherein fishermen reside. The maximum number was in Ramanathapuram district (178) and minimum was in Tirunelveli district (9). The Point Calimere wild life and bird sanctuary (38500 ha) is the only Ramsar site in state. Gulf of Mannar (GOM) Marine national Park (560 Km$^2$) consists of 21 coral island which has high diversity of plants and animals. The *Dugong* (sea cow) the vulnerable marine mammal and *Phycodera fluva*, the endemic Balanoglossus and living fossil are present in GOM.

The rich biodiversity of the state is supported by various ecosystems like mangrove (7315 ha), Coral reef (3899ha), lagoon (25057 ha), reservoir (56419 ha), river and canals

(136878 ha), brackish water (60000 ha), tanks and ponds (56000 ha), continental shelf (3500000 ha), saltpan (326176 ha), estuary (10000 ha), mudflat (33164 ha), creeks (3404 ha), floodplain (7000 ha) and seashore (9798 ha).

Using the Fisheries valuation tool of WRI, the total economic values of provisioning services provided by the fisheries resources was estimated as 20981 million (2010); 23512 million (2011); 21845 (2012); 24834 million (2013) and 33228 million (2014). The monetary value of ecosystem services of ecosystem using value transfer technology are mangrove (₹64666 million), coral reef (₹62634 million) lagoon (₹33044 million) reservoir (₹66076 million), river and canals (₹78103 million), flood plain (₹61881 million), brackish water (₹70270 million), tanks and ponds (₹31954 million), continental shelf (₹354670 million), saltpan (₹66126 million), estuary (₹13187 million), mudflat (₹3360 million), creeks (₹344 million) and seashore (₹241 million). Valuation gives better policy options for the sustainable management of Marine Protected Areas and Marine Bio Reserves of the state.

# Spatial extent assessment of teak defoliator, *Hyblaea puera* (Cramer, 1777) outbreak on mangrove ecosystem along the Vashi creek, Mumbai using satellite data

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The severe outbreak of moth *Hyblaea puera* (Order: Lepidoptera; Family: Hyblaeidae) has affected mangrove forest along the Vashi Creek, Mumbai (Maharashtra, India) during Post Monsoon period (September to November) of 2019. It is known as "Teak Defoliater", is a well known pest causing significant losses to timber production from teak plantation during their seasonal outbreak. Besides the Teak, it also defoliates 45 other host tree species, among these host species, pests have been found to defoliate on the black mangrove (*Avicennia* sp.,) and it has been observed that it has adapted life history trait to suit the micro environmental condition of the mangrove ecosystem. The ecological role of this pest species in the mangrove ecosystem appears to be complex and is less studied. In general herbivory in mangrove forest is minor route for organic matter transfer and typically cause moderate defoliation not exceeding the more than 5% the leaf area. To dates there are very few records containing the detailed information about mangrove herbivory along the Indian coast. There is evidence that heavy defoliation can cause negative affect on the already threatened mangrove ecosystem. The present study tried to assess the mangrove infestation due to outbreak of *Hyblaea puera* along the Vashi Creek, Mumbai.

The present study evaluates the spatial extent of infestation of *Hyblacea puera* on mangrove along the Vashi creek using the satellite data. The satellite dataset used for was SENTINEL 2 and processed using the QGIS platform. The pre infestation mangrove extent mapping was carried out to know the base line information for assessment of defoliation intensity and mangrove extent before infestation along the Vashi creek and estimated mangrove extent was 74.57 km$^2$. The mangrove species that dominate along the Vashi creek are *Avicennia marina* and *Sonnertia apetella*, but mangrove species affected the most was *Avicennia marina*. Leaves of *Avicennia marina* were skeletonized and twigs were heavily defoliated. The study revealed that 67.90% (50.61km$^2$) area of mangrove defoliated due to outbreak of *Hyblaea puera*. Out of total mangrove extent, 30.20 % (22.50 km$^2$) and 37.70 % (28.11 km$^2$) were highly defoliated and less defoliated respectively, while 32.10 % (23.95 km$^2$) of mangrove extent was unaffected.

# Photosynthetic pigments of six sea grass species growing along the Rameswaram coast

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Seagrasses are submerged marine flowering plants grow as thick beds in coastal regions and form one of the most productive ecosystems in the world offering very valuable ecosystem services. Chlorophylls present in their leaf blades are the light harvesting pigments do take pivotal role in primary production. We present here the quantity and composition of chlorophyll pigments as well as the ratio between Chlorophyll *a* to Chlorophyll *b* extracted from six species of seagrasses collected from the seagrass beds of Chinnapalem and Devipattinam coast.

Out of the six species, total chlorophyll (*a*, *b* and *c*) was at the highest in *Cymodocea serrulata* (1066.5 µg. $g^{-1}$ wet wt.) and the lowest in *Syringodium isoetifolium* (510.4 µg. $g^{-1}$ wet wt.). The ratio of chlorophyll *a* to chlorophyll *b* in seagrass leaves generally lies within 2-4. We observed *a/b* values ranging from the highest 3.14 in *Halodule uninervis* and the lowest 1.99 in *Syringodium isoetifolium*. Higher values of *a/b* indicate the seagrass to be growing in stress free environment.

# Taxonomic study of Nemipterids (Perciformes: Nemipteridae) in the north-eastern coast of India

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The north-eastern coast of India is one of the less studied area and an important region from biodiversity point of view. In a recent ichthyofaunal survey conducted for a period of two years (2017-2019) along Odisha coast, seven species of nemipterids namely *Nemipterus randalli*, *N. nematophorus*, *N. peronii*, *N. bipunctatus*, *N. japonicus*, *Parascolopsis aspinosa* and *Scolopsis vosmeri* were collected from Paradeep Fishing Harbour (20⁰ 17.345' N, 086⁰ 42.422' E), and Pentakota Fish Landing Centre (19⁰ 48' 0.8892" N, 85⁰ 50' 48.138" E). The fishes were captured by various gears such as multiday bottom trawls (cod end mesh size 40 mm), bottom set gillnets (58 mm) and long lines (hook no X-XI) operated along coastal waters of Odisha. The present paper describes four species of nemipterids: *N. randalli, N. nematophorus*, *N. peronii,* and *P. aspinosa* for the first time from Odisha coast in the Bay of Bengal. The other three species which have been reported earlier also were identified and reconfirmed for their distribution along the coast. The present record of four species of nemipterids from Odisha coast is not a great surprise as these species are already recorded from other parts along the Indian coast. Since these species occur in neighbouring coasts i.e. West Bengal and Andhra Pradesh, the present record from Odisha coast would not be as a true range extension/expansion of these species. Earlier study dateing back to 2007, reported only four species (*N. bipunctatus*, *N. furcosus*, *N. japonicus*, and *Scolopsis vosmeri*) from the same area by Barman *et al.,* (2007) which might not have covered a thorough sampling effort or may be a misidentification with other species coexisting in the area. The present study has conducted an extensive sampling effort covering the six coastal districts along the Odisha coast for a period of two years and reported four species which is already established in the area. The demand for nemipterids is an all-time high in India due to their good meat texture for the surimi processing industry. These fishes mostly caught by multiday bottom trawls operating at a depth of 40-70 m in the coastal waters of Odisha coast. Along with the industrial demand, these species are also favoured by the local consumers due to its medium cost and delicacy. These reef fishes are also important in indicating the health of the coastal ecosystem (Biswas *et al.,* 2012). The newly reported four species of nemipterids indicated the need for long-term extensive sampling and observation along the coast. This report not only increases the fish diversity of the state but in the future, is useful for studies on the interaction with the other species and the behavioural changes with respect to habitat and climate change. Based on the present study and previous reports, a key to the species of family Nemipteridae so far reported from the north-eastern coast of India along with details description on taxonomic characters for easy identification is provided.

# First report of Cepheid scyphozoan jellyfish *Marivagia stellata* from Palk Bay, south east coast of India

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The family Cepheidae is consisted of four genera and eight species. The Cepheid jellyfish *Marivagia stellata* is an Indian Ocean jellyfish, however this has been described only in 2010 when this species was collected from the Mediterranean coast of Israel. *Marivagia stellata* differ from other Cepheid genera viz., like *Cephea* and *Netrostoma* by the absence of warts or knobs centrally on the exumbrella and filaments on oral disk and between mouths. Further, this species differ from *Cotylorhiza* by lacking stalked suckers and filaments on the mouth arms. Only in 2013, this species was reported from Kerala coast, though this species is of Indian Ocean origin. During a regular survey along the Palk Bay on 25th July 2018, sixteen specimens of *Marivagia stellata* were collected from Shore-seine operation at Dhargavalasai (9.326781 N, 79.023664 E). This is the first report of its occurrence along the East coast of India. The specimens were in the bell diameter range of 5.16±0.38 cm and the weight range was observed in the range of 15.4±2.74 grams respectively. *Marivagia stellata* is considered to be an invasive species other than its native range viz., Indo-Pacific. This species has been termed as Lessepsian migrant and through Suez Canal, it established its population in the Mediterranean Coast of Lebanon, Israel and Northern Levantine Coast of Syria. In general, the sting of *Marivagia stellata* do not cause any harm to humans and no effect is felt.

# Diversity of fishes, crustaceans and molluscs in the traditional prawn filtration fields

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In North Kerala (South India) there exists a unique system of farming shrimp alternated with paddy which is known as *kaipad* prawn filtration. The *Kaipad* wetland ecosystems in general consist of marshes, swamps, ponds and paddy fields. These areas experience flood during monsoon and salinity intrusion during summer, owing to their proximity to estuaries. Saline water from the sea enters the estuaries during summer when the flow from the rivers is low and it reaches the low lying *kaipad* wetlands during summer months. The cultivation of paddy in these fields is restricted to a single crop from July to September when the surrounding backwaters are low in salinity. After harvesting the paddy crop by October, the bunds provided with sluice gates are strengthened, and the water brought in by the high tide is allowed to enter the fields through the sluice gates. Juveniles of shrimps and fishes enter into the field through the incoming water. Since these ponds are tidally fed, there is no control over the salinity and other physico-chemical parameters of the water.

The present study was carried out to document the diversity of fishes, crustaceans and molluscs in these traditional pawn filtration fields during 2017. Occurrence of fishes and shell fishes were collected from 32 prawn filtration fields on a monthly basis. The results of the present study showed that *Kaipad* prawn filtration fields have an impressive richness of fish and shell fish species. These fields were found to have 74 species of fishes belonging to 34 families, 16 species of crustaceans belonging to 7 families and 9 species of molluscs belonging to 6 families. Highest number of species was found to be in Ariidae (5), Clupeidae (5), Cyprinidae (5) and Mugilidae (5) followed by Ambassidae (4), Leignognathidae (4), Lutjanidae (4), Sciaenidae (4), Bagridae (3), Cichlidae (3), Aplocheilidae (2), Belonidae (2), Carangidae (2), Engraulidae (2), Hemirhamphidae (2), Polynemidae (2) and Sillaginidae (2). *Oreochromis mossambicus*. The crustaceans were dominated by family Penaeidae (6) followed by Palaemonidae (3), Grapsidae (2), Ocypodidae (2). Among molluscs, the dominated families were Ostreidae (2), Potamididae (2) and Veneridae (2). As per the IUCN grouping, among the fin fishes, two species each were belonged to Near Threatened (NT) and Vulnerable (V) categories. Forty five (45) species of fishes belonged to the Least Concern (LC) category, 21 species were in Not Evaluated (NE) category and four species were in Data Deficient (DD) category. Among the crustaceans three species belonged to LC and 13 species to NE category. Among the molluscs two species belonged to LC and seven in NE category.

Biodiversity and richness indices like Margalef's diversity index (7.55), Simpson's Index (0.93) and Shannon-Wiener diversity index (3.22) showed a higher diversity and evenness in these fields. The study highlights the need to promote organic shrimps faming adopting traditional technology for developing a sustainable system which supports the biodiversity.

The lowest number of species was noticed in the month of June and the highest in the month of April. The number of species for different months being, July: 28, August: 30, September: 41, October: 47, November: 51, December: 53, January: 54, February: 56, March: 58 and April: 62. Thereafter, the number of species showed a declining trend to reach 44 in the month of May and 21 in the month of June. The observation was true in the case of fin fishes, crustaceans and mollusks, alike.

# Schyphozoan and Cubozoan Jellyfish Diversity along Northeast Coast of Tamilnadu

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Frequent swarming of jellyfish in recent years, is of great concern all over the world as it either directly (stinging humans, clogging of nets and desalination plants etc) or indirectly (predation and association with other organisms) interferes with human life. Collection of time series data on the species diversity, swarming activity, biology and the population dynamics of jellyfish would help to frame proper management measures, which might help to manage this situation.

Though all the gelatinous zooplanktons in the ocean are in general termed as Jellyfish, the true jellyfishes are seasonally swarming Cnidarians that come under the class Hydrozoa, Scyphozoa and Cubozoa. Scyphozoan jellies are the most beautiful ones known for their elegant movement with colourful dome shaped pulsating bells and trails of long and beautiful arms and tentacles. Some of them cause itching but are not fatal. The cubozoan jellies (called as box jellies) possess cube shaped medusa. Some species of box jellies produce extremely potent venom which is extremely painful and fatal to humans.

Jellyfish samples were collected from following fishing villages, namely, Indira Gandhi kuppam, Ernavoor kuppam, Ennore, Nochikuppam, Thiruvanmiyurkuppam, Kovalam, Thiruvidanthai, Soolerikattu kuppam, Devanerikuppam and Cuddalore Aalikuppam; along northeast coast of Tamilnadu. Local fishermen were engaged for collection of jellyfish. They used fibre boats with outboard engine and gillnet for fishing of jellyfish. Majority of the specimens were obtained from 15-20 metres depth range. Water samples were collected from the jellyfish fishing sites and analysed for salinity, PH, dissolved oxygen and nutrients. The collected specimens were identified upto species level followed by measurement of disc diameter and weight. Tissues were preserved in alchohol for further study and necessary specimens were preserved in formalin.

A total number of 15 species belonging to 11 genera, 4 orders and 3 classes were recorded. Twelve species, namely, *Acromitus flagellatus, Chrysaora hysocella, C. calyparea, C. quinqecirrha, Catostylus mosaicus, Cephea coerulea, Crambionella stuhlmanni, Cyanea capillata, Desmonema gaudichaudi, Marivagia stellata,Thysanostoma flagellatum, T. loriferum* belonged to Class Scyphozoa; One species, *Tamoya haplonema* belonged to Class Cubozoa, and two species, *Aequorea forskalea* and *A. pensilis* belonged to the Class Hydrozoa.

The *Acromitus flagellates* obtained from estuarine habitat (1-2 metres depth range) had bell diameter ranging from 40-325 mm and weight 2-1950 grams. *Acromitus flagellates* were mostly cream in colour with either plain or spotted (brown spots varied in intensity and pattern) bell. Among sea nettles, *C. hysocella* dominated the population followed by *C. quinquecirrha* and *C. calyparea.* The sea nettles were found associated with acetes, brittle stars, larvae of carangids and flatfish and juveniles of *Stolephorous* sp., *Pomodasys* sp., *Sphyraena* sp., *Scomberomorous* sp., *Secutor* sps., *Scleroides leptolepis* and *Lactarius lactarius*. The Lion's mane jellyfish (the largest among jellyfish) represented by *Cyanea capillata* and *Desmonema gaudichaudi* seemed to occur together throughout the year. The maximum disc width of *Cyanea capillata* was 605 mm and maximum weight was 14.4 kg. Maximum disc width of *Desmonema gaudichaudi was* 525 mm and maximum weight was 8.7 kg. The edible *Crambionella stuhlmanni*, which formed a fishery earlier, doesn't seem to have any fishery along Chennai coast at present. *Cephea caerulea, Marivagia stellata, Thysanostoma flagellatum* and *T. loriferum* are very beautiful purple coloured jellies which can be of very high ornamental value. The only box jellyfish obtained was the poisonous *Tamoya haplonema* which was a medium sized one with maximum box length of 101 mm and weight of 155 grams. The harmless crystal jelly *fish, Aequorea forskalea and A. pensilis* always existed together in the ratio of 1:20. The gelatinous *Aequorea forskalea* had soft bell which gradually became thinner towards the margin and had more than 60 radial canals. The transparent pale white jellyfish *Aequorea pensilis* had thick disc and spring-like tentacles. This crystal clear, itch free disc, looked like palm fruit and liquefied with time. Further investigations on the fishery and biology of this pre-Cambrian group, is likely to provide information on its role in food web besides meeting the food and medicinal needs of human beings.

# Studies on the community structure of epibenthic Ciliates from soil habitat of a mangrove ecosystem in the southern coast of India

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The present study evaluates the biocoenosis of epibenthic ciliates from the mangrove ecosystem of Ayiramthengu mangrove ecosystem in the southwest coast of India. The study was done in alternate months from June 2014 to May 2015 and samples were collected from the mangrove soil. Ecological parameters like water temperatures, pH, dissolved oxygen, conductivity, salinity, nitrate, phosphate and sulphate were also analyzed during the study period. The mangrove soil consisted of 85 species belonging to 13 subclasses Bicosidae, Cyrtophoria, Haptoria, Heterotrichea, Holotrichia, Nassophorea, Peniculia, Peritricha, Phyllopharyngea, Protocruziidia, Scuticociliatia, Spirotrichea and Suctoria. Among them, spirotrichea occupies the dominant portion (43%) followed by phyllopharyngea (24%) and peniculia (9%). *Chlamydodon mnemosyne* was the most dominant ciliate (1,095 no./cm$^2$) followed by *Chlamydodon pedarius* (1095 no./cm$^2$). The effects of ecological parameters in the community structure of epibenthic ciliates were evaluated. Maximum number of ciliates (2787 no./cm$^2$) and maximum shannon diversity index (1.692) was observed in January and the minimum number of ciliates (1803 no./cm$^2$) and minimum shannon diversity was observed in May (1.477). Similarly maximum species richness was recorded in may (25.79) and minimum recorded from January (24.38). The study reveals the importance of ecological parameters on the distribution of epibenthic ciliates on mangrove soil.

# Bioinventorisation and economic valuation of fishery resources in the marine and coastal ecosystems of Andhra Pradhesh

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Andhra Pradesh with a coastline of 980 km has rich marine fishery resources accounting for an average marine fish production of 2, 85,640t. It has a vast continental shelf area of 31000 km$^2$ bordering nine coastal districts namely Srikakulam, Vizianagaram, Visakhapatnam, East Godavari, West Godavari, Krishna, Guntur, Prakasam and Nellore. The state receives enormous rain both south-west and north-east monsoons and abundant discharge from the two big rivers Godavari and Krishna, which supports the prolific growth of vast flora and fauna.

The commercial fisheries revenues and costs are calculated following the World Resources Institute Fisheries Valuation Tool (WRI, 2007). The basic framework for value transfer methodology includes five steps as described by Troy and Wilson (2006).

Ecosystem services provided by the marine and coastal ecosystems of Andhra Pradesh fall into four groups such as Provisioning services, Regulating services, Cultural and Recreational services and Supporting services. Major regulating services such as biological regulation, fresh water regulation, gas regulation, hydrologic balance, water regulation, atmospheric and climate regulation, shoreline protection, creeks, rocky shores, mangroves, carbon sequestration and habitat protection provided by the coastal and marine ecosystems of the state. Cultural and recreational services include beach tourism, ecotourism, boating, spiritual services, heritage value, education and research. Supporting services include nutrient cycling, habitat for migratory and resident species of fish, birds, marine mammal and reptiles. Major drivers of the reduction in the ecosystem services are the anthropogenic and natural impacts, land use change, habitat loss, over exploitation of fisheries, invasive species, water pollution, industrial pollution, sewage, eutrophication, fragmentation of water bodies and climate change.

Bioinventory of the ecosystems in the state reveals the species richness and diversity contributed by a total of 960 species of fishes, followed by 132 species of molluscs, 65 species of crustaceans, 50 species of echinoderms, 87 species of macroalgae and 25 species of mangroves. Major provisioning ecosystem services provided by fisheries includes finfish, shark, tuna, shrimp, crab, cephalopod, bivalve from capture fisheries and finfish and prawns from aquaculture

New additions to coastal ecosystem of Andhra are Ragged Sea Hare (*Bursatella leachii*), Leatherback turtle (*Dermochelys coriace*), flat elbow crab (*Aethra edentate*)and decapods crustacean sand crab (*Albunea symmysta*), Indian golden barred butterfly fish (*Roa jayakari* ), Titan trigger fish (*Balistoides viridescens*), black spot sturgeon fish (*Acanthurus bariene*), Pacific Gregory (*Stegastes fasciolatus*), White spot sand smelt (*Parapercis alboguttata*), African spade fish (*Tripterodon orbis*) and silver moony (*Monodactylus argenteus*).

The rich biodiversity of the state is supported by various ecosystems like mangrove (41486 ha), lagoon (47407 ha), reservoir (404499 ha), river and canals (385839 ha), brackish water (60000 ha), tanks and ponds (517000 ha), continental shelf (3100000 ha), saltpan (17725 ha), estuary (26000 ha), mudflat (2500 ha), creeks (9594 ha) and seashore (3700 ha). Using the Fisheries valuation tool of WRI, the total economic values of provisioning services provided by the fisheries resources were estimated as 10585 (2010); ₹11913 (2011); ₹11520 (2012); ₹15168 (2013) and ₹16077 (2014). The monetary value of ecosystem services of ecosystem using value transfer technology is mangrove (₹366745 million), lagoon (₹62518 million), reservoir (₹473742 million), river and canals (₹220163 million), brackish water (₹70271 million), tanks and ponds (₹295005 million), continental shelf (₹314136 million), saltpan (₹3593 million), estuary (₹34286 million), mudflat (₹253 million), creeks (₹972 million) and seashore (₹91 million).

The high productivity of coastal area is coupled with high vulnerability to natural disasters and pollution which directly affects the human well-being and livelihood of fishermen population. Biodiversity value of ecosystem services will provide policy options to conserve and protect the ecosystem services which directly correlated to human well-being and will be considered a right step in the science.

# Economic valuation of marine ecosystems: a case study of Devagudda Island ecosystem, Karnataka, India

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Global biodiversity is very rich in flora and fauna spread across many eco systems like terrestrial and marine (aquatic) ecosystems. The biodiversity is gradually under degradation due to many factors among which the anthropogenic activities are the most serious one. The impacts of such activities are usually cumulative, realized at a much later date thus leading to irreversible damage to the biodiversity as well as ecosystems in which they are a part.

Island eco systems are very sensitive, fragile and threatened by anthropogenic activities as well as other abiotic and biotic changes. This stresses the need to know the value of these ecosystems and also the socio economic status of the intrinsic inhabitants or users of these eco systems to have comprehensive understanding of the situation. This will also help in formulating suitable management or policy measures for conservation of the ecosystem as well as bio-diversity. With this theme in focus, a study was undertaken to value the Devagudda Island ecosystem of Karnataka State using the Millennium Ecosystem Assessment (MEA) (UNEP 2006)

The MEA approach classifies the ecosystem services into four broad categories namely (i) Provisioning Services comprising food, fresh water. fuel-wood and bio-chemicals; (ii) regulating series comprising climate regulation, carbon Sequestration, water purification and pollination; (iii) supporting services comprising soil formation, nutrient cycling and primary production and (iv) cultural services comprising recreation and tourism, aesthetic value and spiritual & religious activities

Based on this MEA approach, the total economic value of DevaguddaIsland Ecosystem, Karnataka was estimated at INR 747.74 million (US$ 11 million). This included, the values of provisional services, at INR 366.90 million (US$ 5.4 million), regulating services, at INR 375.53 million (US$ 5.52 million), supporting services at INR 3.88 million (US$ 0.06 million) and cultural services at INR 1.43 million (US$ 0.02 million). Policy implications for marine biodiversity conservation are also discussed.

# Plankton composition in lagoons of Chetlat and Kiltan Atolls, Lakshadweep Archipelago, India

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Phytoplankton and zooplankton collected from the lagoons of Chetlat and Kiltan Islands of Lakshadweep during March, 2015 were studied. 13 genera of phytoplankton were recorded from Chetlat while 11 genera were observed from Kiltan. Quantitative studies on phytoplankton indicated that more concentration (1300 numbers per $m^3$) was recorded from Chetlat than from Kiltan (640 numbers per $m^3$). In both the lagoons, *Trichodesmium* sp. was the dominant genus constituting 31% at Chetlat and 34% at Kiltan. 13 groups of zooplankton were recorded from Chetlat as well as from Kiltan. The displacement volume of zooplankton was the same in both the Islands (4.5 ml per 100 $m^3$). The concentration of zooplankton in Chetlat was 4070 numbers per 100 $m^3$ while that of Kiltan was 4884 numbers per 100 $m^3$. In both the lagoons, copepod was the major component of zooplankton (45% at Chetlat and 54% at Kiltan) followed by crab larvae (31% at Chetlat and 23% at Kiltan). Both qualitative and quantitative abundance of phytoplankton and zooplankton in lagoon areas of Chetlat and Kiltan were described and discussed.

# Sponge diversity of Thonithurai and Kilakarai areas of south-east coast of India

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Gulf of Mannar (GOM) is rich in terms of diversity and abundance of sponge fauna and past research revealed presence of several species new to science and new records from this area (Dendy, 1905; Burton, 1930, 1937; Rao, 1941; Thomas, 1968-1970). For the present investigation the 116 sponge samples were collected during July 2018 to May 2019 from Mandapam (9°16'39.38"N & 79°7'53.60" E), Keelakarai (9°13' 38.30"N & 78°47'21.10"), Thiruppalaikudi (9°32'52.43" N & 78°55'12.02" E), Thonithurai (9°17'20.89" N & 79°17'20.89" E ), and Vedalai (9°15'46.20"N & 79° 6'11.46" E ). The samples were collected by handpicking, SCUBA diving and preserved. The sponges entangled in gillnet were also collected and preserved. Sponges were digested separately by boiling small pieces in con.HNO3 and Sodium hypochlorite. They were passed through three changes of distilled water and absolute alcohol series. The spicules were dried and mounted on a glass slide using mounting medium DPX. Detailed examination of all the type specimens of sponges deposited in the Mandapam museum was carried out during May 2019. Details regarding morphology, color, consistency, spicules, and skeletal structures were recorded for systematic identification of the species. A list of sponge species hitherto recorded from the area is given.

Major encrusting and boring species reported in the present study were *Siphonodictyon diagonoxeum* (Thomas, 1968), *Siphonodictyon minutum* (Thomas, 1972), *Spiroxya acustella* (Annandale, 1915), *Cliona celata* Grant, 1826, *Pione vastifica* (Hancock, 1849), *Cliona lobata* Hancock, 1849, *Cliothosa quadrata* (Hancock, 1849), *Cliona viridis* (Schmidt, 1862), *Cliona orientalis* Thiele, 1900, *Cliona delitrix* Pang, 1973, *Cliona varians* (Duchassaing & Michelotti, 1864). *Hyattella intestinalis* (Lamarck, 1814), *Dysidea fragilis* (Montagu, 1814), *Haliclona (Haliclona) oculata* (Linnaeus, 1759), *Gelliodes fibrosa* Dendy, 1905, *Haliclona (Gellius) fibulata* (Schmidt, 1862), *Callyspongia (Cladochalina) diffusa* (Ridley, 1884), *Echinodictyum clathratum* Dendy, 1905, *Clathria (Clathria) gorgonioides* (Dendy, 1916), *Myxilla (Ectyomyxilla) arenaria* Dendy, 1905, *Lissodendoryx (Ectyodoryx) lissostyla* (Thomas, 1970), *Hymedesmia (Hymedesmia) mannarensis* Thomas, 1970, *Hymedesmia (Hymedesmia) stylophora* Thomas, 1970, *Endectyon (Endectyon) hornelli* (Dendy, 1905), *Aulospongus tubulatus* (Bowerbank, 1873), *Clathria (Microciona) atrasanguinea* (Bowerbank, 1862), *Mycale (Arenochalina) trincomaliensis* Rao, 1941, *Mycale mannarensis* Thomas, 1968, *Mycale (Mycale) monanchorata* Burton & Rao, 1932, *Artemisina indica* (Thomas, 1974), *Axinella donnani* (Bowerbank, 1873), *Axinella ceylonensis* (Dendy, 1905), *Halichondria (Halichondria) panicea* (Pallas, 1766) and *Echinodictyum flabelliforme* (Keller, 1889). Past studies reveal that about 275 sponges occur in GOM area. They are distributed in Gulf of Mannar Biosphere Reserve (GOMBR) which includes 7 islands of Mandapam area, 7 islands of Keelakarai region, 3 islands of Vembar and 4 islands of Tuticorin area. They are abundant in 0-30m depth along with softcorals and gorgonids. The detailed systematic account of the sponge species reported from Mandapam area was reviewed. The most interesting fact of the sponges of GOM ecosystem is the presence of 31 endemic species which needs to be conserved and protected.

# Taxonomy and biodiversity of marine sponges off Gulf of Kutch, Gujarat, India

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The Gulf of Kutch (GoK) Marine National Park and Sanctuary is located in Devbhoomi Dwarka, Jamnagar and Morbi districts along the Gujarat coast of India (20° 15'N to 23° 40'N L and 68° 20' to 70° 40' E) which covers an area of 620.81 Km² with 42 islands supporting coral reefs, mudflats, rocky areas, mangrove, seagrass beds, salt pan and intertidal areas. GoK is rich in biodiversity and is one of the most ecologically and biologically significant areas along the west coast of India. The sponge fauna of GoK is rich in terms of numbers and diversity, especially coloured varieties of encrusting sponges (Fig. 1). The vast area of the intertidal zone of GoK provides an excellent habitat for the varieties of sponges occurring in this area; especially sponges of different colors, varieties, solitary and associated with coral reefs were also observed. GoK has the first marine protected area of India where few investigations on the sponge diversity were undertaken in the past. The sponge research along GoK dates back to the period of James Hornell (1905) followed by Dendy (1916) and Thomas *et al.* (1996). Pioneered work by Hornell from Okha included 64 species of sponges consists of 6 species of calcareous sponges.

The present work on sponge taxonomy and diversity of GoK was undertaken to meet the objectives of AICOPTAX project sponsored by Ministry of Environment, Forest and Climate Change, Government of India. This study includes survey and sampling carried out

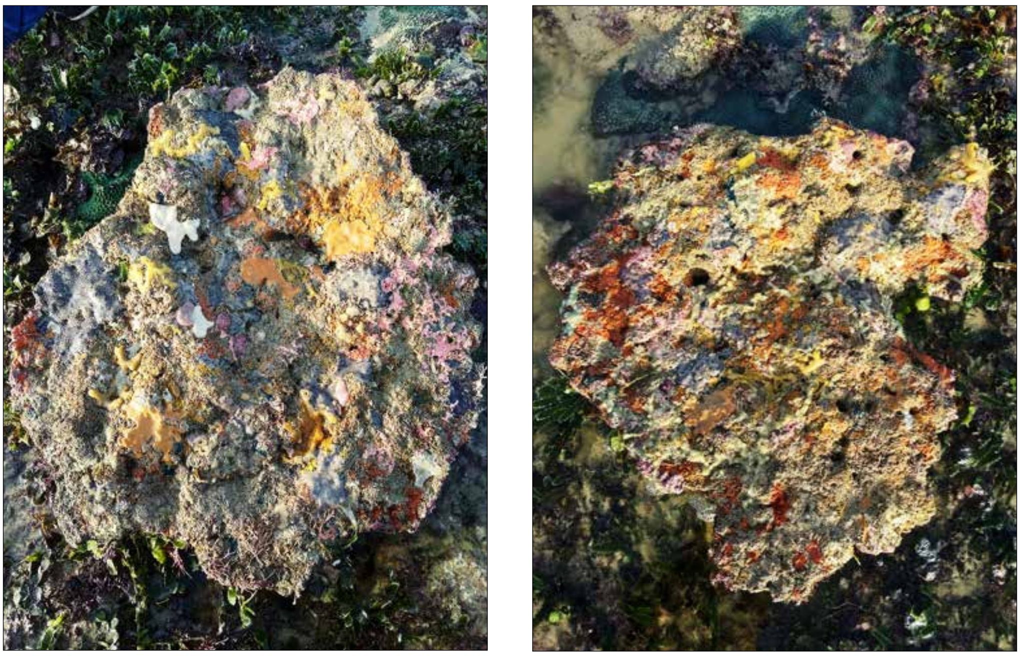

Fig. 1 Colorful encrusting marine sponges exposed during the lowest low tide off the Gulf of Kutch

during May-July 2019 at Okha (22°27'18.73"N & 69 ° 04'49.39"E), Mithapur (22°23'36.51"N & 69°02'15.51"E), Shivrajpur (22°18'23.52"N & 68 °55'57.72"E), Poshitra (22°22'57.49"N & 69 °09'38.31"E) and Beyt Dwarka (22°26'51.02"N & 69 °06'43.84"E). The on-site observations were recorded from exposed sponges during lowest low tide and other times using SCUBA diving supported by a survey vessel. The representative samples were collected and prepared for spicules extraction by placing 1 cm X 1 cm separately in concentrate Nitric acid and Sodium hypochlorite. The samples were extracted, washed thoroughly using Ethanol series and finally preserved in 70% Ethanol. The samples were observed at 80x magnification under Nikon SMZ 1000 microscope. The sponges were identified using Systema Porifera, a guide to classification of sponges by Hooper and Van Soest. Systematic database regarding morphology, color, spicule, consistency, skeletal structures and GIS based habitat data were created.

Important species reported in the present study were *Jaspis reptans* (Dendy, 1905); *Tethya seychellensis* (Wright, 1881); *Chondrilla australiensis* Carter, 1873; *Tetilla dactyloidea* (Carter, 1869); *Cinachyrella hirsuta* (Dendy, 1889); *Gelliodes fibrosa* Dendy, 1905; *Halichondria (Halichondria) panicea* (Pallas, 1766); *Callyspongia crassifibra* (Dendy, 1889); *Haliclona pacifica* Hooper & Wiedenmayer, 1994; *Phakettia virgultosa* (Carter, 1887); *Axinella donnani* (Bowerbank, 1873); *Auletta elongata* Dendy, 1905; *Iotrochota baculifera* Ridley, 1884; *Myxilla (Ectyomyxilla) arenaria* Dendy, 1905; *Clathria (Thalysias) procera* (Ridley, 1884); *Clathria (Clathria) gorgonioides* (Dendy, 1916); *Phakellia radiata* (Dendy, 1916); *Cliona varians* (Duchassaing & Michelotti, 1864); *Suberites carnosus* (Johnston, 1842); *Darwinella australiensis* Carter, 1885; *Mycale (Zygomycale) parishii* (Bowerbank, 1875); *Biemna fortis* (Topsent, 1897); *Spheciospongia vagabunda* (Ridley, 1884); and *Cliona celata* Grant, 1826.

The present information about the species diversity of sponges of GoK is significant due to the vast area of high tidal influx which is affected by several anthropogenic and natural factors including sedimentation, industrial and domestic pollution, land run off of nutrients, oil spills, etc. which damages the habitats. This results in the reduction in the diversity of sponges along GoK area. The present study also helps in the management and conservation of biodiversity of the GoK Marine National Park and Marine Sanctuary.

# Morphological and genetic tools for differentiation of squid species *Uroteuthis duvaucelii, Uroteuthis edulis, Uroteuthis singhalensis* and *Loliolus hardwickei* from Indian Ocean

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The family Loliginidae comprises many ecologically and economically important species. They currently include 10 genera (*Sepioteuthis, Doryteuthis, Loliguncula, Alloteuthis, Afrololigo, Heterololigo, Loligo, Pickfordiateuthis, Loliolus* and *Uroteuthis)* and more than 50 species that are distributed in Pacific, Atlantic and Indian Oceans. They have been playing a pivotal role in neurophysiological research owing to the presence of its giant axon. Despite its wide usage in genetics, identification of some loliginids based on traditional morphological techniques remains problematic due to its close phenotypic relationships and the occurrence of cryptic species among them.

Present study characterized some important morphological features to distinguish *Uroteuthis* species, *Uroteuthis duvaucelii (Orbigny*, 1835), *Uroteuthis edulis (Hoyle, 1885)* and *Uroteuthis singhalensis* (Ortmann, 1891) and Loliolus species *Loliolus hardwickei* (Gray, 1849) from Indian Ocean. We also analysed the mitochondrial barcode region (COI gene) of these species by using PCR amplification and Sanger sequencing. Intra and interspecific genetic distance were also calculated for all species from Loliginidae family.

Uroteuthis species resemble each other morphologically and are distinguishable by their fin shape and arm sucker dentition. *L. hardwickei* is easy to identify owing to its small size, heart-shaped fin, a large proximal crest and complete hectocotylization. The sharpness of tentacular teeth was observed to be increasing in the order *U. edulis* < *U. duvaucelii* < *U. singhalensis*. Number of arm teeth was highest in *U. edulis* and almost the same in both *U. duvaucelii* and *U. singhalensis*. COI gene (650bp) sequence analyses substantiated the results obtained from morphological analysis. Generated sequence of *U. duvaucelii* and *U. edulis* shown 100% sequence similarity with the corresponding species reported from Indo-Pacific Ocean. Present study reported COI gene sequence data from *U. singhalensis* and *L. hardwickei* from Indian Ocean region for the first time. At the genus level among Loliginids, highest genetic distance was observed between Uroteuthis and Sepioteuthis (21.03%) and lowest observed was between Uroteuthis and Loliolus (16.17%). At the species level among Uroteuthis sp., the lowest genetic distance was observed between *U. duvaucelii* and *U. singhalensis* (12.69%) and the highest between *U. singhalensis* and *U. edulis* (19%33).

The accurate identification of specimens is of paramount importance when it comes to delineating cryptic groups. The present study outlines a quick and easy method to accurately identify the squid species of Loliginidae family by using conventional morphological taxonomic tools and the results obtained has been validated by modern molecular tools. Further studies are needed with large number of samples representing actual Loliginidae diversity and more molecular markers to delineate evolutionary relationships among them.

# Jelly fish diversity and swarming patterns along Thiruvananthapuram coast, south west coast of India

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Swaming of jelly fishes along the coast and adjoining backwater areas is a common phenomenon usually during coast monsoon. The main reason for swarming behavior is believed to be for sexual reproduction. The beach seine operation in southern coast of Kerala hauls in several tons of jellyfishes during their operation along this coast, creating a nuisance situation for the fishers. The swarming of jellyfishes along the Thiruvananthapuram coast was monitored and their diversity, abundance and season and pattern of swarming recorded along the coastal waters.

Regular sampling was carried out for three years since 2016 along Thiruvananthapuram coast. Major shore seine operation area like Pozhiyoor, Poovar, Kovalam, Shangumukhom, St. Andrews, Puthenthope, Perumathura, Edava, ring seine operation centres in Thazhampally and Kappil backwaters were selected for detailed study. Morphological characters of the jeely fishes were recorded for species level identification. Samples were also collected for DNA analysis for further confirmation and clarification of identified species.

The present investigation on Jelly fish diversity and distribution has recorded 12 species of Scyphozoans belonging to 8 families and one each in Cubozoa and Hydrozoa. *Crambionella orsini* was the common swarming species noticed in the shore seine operating along southern centres whereas their incidence is very less in other places. Two species of belonging to the genus *Cyanea* (Scyphomedusae ) were observed in high abundances during September-November period. Both species were frequently encountered in shore seines operated along northern villages from Perumathura to Kappil and also in other gears such as gill nets and ring seine operated in the nearshore waters. Swarming of *Lychnorhiza malayensis*, *Chrysaora* sp., *Netrosoma* sp. was also observed along the coast. Incidences of jellyfish blooms resulted in the loss of many fishing days as huge size jelly fishes hindering the shore-seine fishing activity, where manual labour is employed to drag the net. In other fishing activity such as gill nets and ring seine also face major problem due to this menace causing considerable economic loss to fisher folks. Swarming of cubozoid jelly fish *Chiropsoides buitendijki* was noticed in disco nets (Trammel net) operated from Thazhampally during monsoon season. It was noticed that medusa of most of the species was accompanied by Anchovies, Silver bellies and juveniles of clupeids and mackerel sheltering under its umbrella among the filamentous mouth and arms. Regular swarming of *Acromitus flagellatus* was observed in Kappil Backwaters during summer months usually from February to April. This species showed different chromatophore patterns on its umbrella. Eight type specimens having different chromatophore patterns were collected from this area.

The studies on jelly fish biology, population and nature and reasons for their swarming have traditionally been understudied except some scanty reports on swarming on different areas from both the coasts. Though several environmental problems attribute to increase in blooming of jelly fishes like climate change, pollution, overfishing of predatory fishes, increased artificial structures in the sea which supports increase in larval settlement etc; there is an imperative need for a holistic approach for the problem covering all aspects.

# Biodiversity valuation of marine resources along the Kerala coast-a comparative analysis for the period 2010-2014

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Marine and coastal ecosystems of Kerala are one of the most productive and unique ecosystems which provide services like fisheries, aquaculture, agriculture, water regulation, shoreline protection and recreational services. The purpose of the present paper is to estimate the values of ecosystem services along the coastal and marine areas using the Total Economic Value (TEV) and Value Transfer (VT) methodologies. Importance of ecosystem services to the human welfare has been already well known. Millennium ecosystem assessment defines ecosystem services and is classified into four major categories like provisional services, regulating services, supporting services, and cultural services. Although there are several investigations of the biology and ecology of marine flora and fauna, studies on the ecosystem services and valuation are very few. The recent decline of fishery resources of Kerala and the steady increase in the human population necessitates a study on the ecosystem services and their values along the marine and coastal ecosystems of Kerala.

Standard methods and equations were followed for the valuation of ecosystem services such as regulatory services, supporting services, cultural and provisioning services. Value transfer methodology is very useful in quickly estimating the economic values associated with different services. The basic framework for value transfer methodology includes five steps as described by Troy and Wilson (2006).

Two charismatic species of Kerala marine fisheries are the Indian Oil sardine (*Sardinella longiceps*) and Indian Mackerel (*Rastrelliger kanagurta*). The species showed decline in the fishery was catfishes, mainly due to the overexploitation of the stock. Among crustaceans, penaeid prawns such as *Penaeus indicus, P. monodon, P. semisulcatus, Parapenaeopsis stylifera, Metapenaeus dobsoni*, *M. monoceros* are contributing to the biodiversity value of the inshore ecosystem. Bivalves provide important provisioning service and species such as *Villorita cyprinoides, Paphia malabarica, Meretrix casta, Marcia opima, Perna viridis, P. inidica, Crassostrea madrasensis* and *Saccostrea cucullata* are mainly exploited from the Vembanad Lake, Ashtamudi lake and Malabar area. Seer fishery is supported by *Scomberomorus commerson, S. guttatus, Acanthocybium solandri* and is considered as high value fishes.

The rich biodiversity of the state is supported by various ecosystems like mangrove (65000 ha), lagoon (38442 ha), reservoir (26167 ha), rivers and canals (65162 ha), brackish water (430000 ha), continental shelf (25000 ha), estuary (100000 ha), creeks (80 ha), flood plain (180000 ha) and seashore (2354 ha). Using the Fisheries valuation tool of WRI, the total economic values of provisioning services provided by the fisheries resources were estimated as ₹24917 (2010); ₹25866 (2011); ₹26244 (2012); ₹37149 (2013) and ₹42933 (2014). The monetary values of ecosystem services using value transfer technology are mangrove (₹574613 million), lagoon (₹50695 million), reservoir (₹30646 million), rivers and canals (₹37182 million), brackish water (₹503608 million), continental shelf (₹2533 million), estuary (₹131871 million), creeks (₹8 million), flood plain (₹1591237 million) and seashore (₹57 million).

The present study gives insight into the ecosystem services and their values occurring along the marine and coastal ecosystems, which is the first attempt and will form the baseline data for the future research work on the valuation and prediction of biodiversity value on the human well-being and sustainability of the marine fishery resources. The valuation results show that Kerala state has one of the most valued ecosystems in the world which may be attributed to the high production along the coast-the mud bank formation, two monsoon seasons, moderate temperature regime, an abundance of nutrients from river runoff and upwelling and wetland ecosystems. Besides these, the age old practices of rice cum prawn and fish culture systems such as Pokkali, Kaipad, Kole wetlands and Kuttanad along with the coconut plantations in the coastal regions enhance the different ecosystem services and results in higher values.

# Seasonal variability of phytoplankton in the Cochin and Ashtamudi estuary

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Studies on the seasonal variability of phytoplankton in the Cochin and the Ashtamudi estuaries of Kerala- Southwest coast of India were carried out. Salinity was the most fluctuating factor among hydrographic parameters throughout the study period in the estuaries. Relatively higher salinity was observed in Ashtamudi estuary than that of Cochin estuary whereas the nutrients were higher in Cochin estuary. Maximum salinity was observed during the pre-monsoon season and the other hydrographic parameters such as dissolved oxygen and nutrients were high during the monsoon season. Seasonal variation of phytoplankton was prominent in both the estuaries with relatively high standing stock in the Cochin estuary. Maximum abundance of phytoplankton was observed during monsoon in the Ashtamudi and pre-monsoon in the Cochin estuary. Phytoplankton taxa represented by three major groups viz., Diatoms, Dinoflagellates and Blue-green algae. *Skeletonema costratum, Thalassiosira subtilis, Leptocylindrus danicus* and *Cyclotella meneghiniana* were the most abundant species observed during the study.

Samplings were carried out along the Cochin and Ashtamudi estuaries during the period of 2018 to 2019. Ten stations (five stations from each) distributed within the area of 10 km from the bar mouth region of the estuaries were selected for the study. Water samples for hydrographic parameters such as temperature, salinity, dissolved oxygen and nutrients were collected and analysed using standard protocols. Phytoplankton (<20m ) samples were collected and preserved according to the standard procedure from the surface waters. Taxonomic analysis were done up to lowest possible taxa (Thomas 1977).

Relatively higher temperature observed during pre-monsoon in the Cochin (31$^{0}$C) and Ashtamudi (32$^{0}$C) estuary with a marginal variation between the seasons. Maximum Salinity also recorded during pre-monsoon in both the Cochin (27psu) and the Ashtamudi (29psu) estuaries with a prominent seasonal variation. On comparison, Ashtamudi estuary sustained relatively high saline water than Cochin estuary (avg. 23). Dissolved oxygen varied between 3.5 mg/l–5.05mg/l and 3.9 mg/l -5.32 mg/l in Cochin and Ashtamudi respectively. Besides these, Cochin estuary have high nutrient loading than that of Ashtamudi estuary with high value during monsoon season (NO3 2.18 μM, 0.84 μM; PO4 2.95 μM, 0.8 μM; SiO4 3.65 μM, 2.6 μM; and NH3 2.49 μM, 1.25 μM respectively in Cochin and Ashtamudi). Heavy river runoff during the monsoon season brings more nutrients in to the estuaries. Human interferences such as industrialisation, urbanization etc. were also responsible for relatively higher nutrients and low dissolved oxygen in the Cochin estuary. Similar pattern in hydrographic parameters were also noticed in the Cochin and Ashtamudi estuary from previous studies (Sujatha *et al.* 2009).

Cochin estuary supports relatively high phytoplankton abundance than Ashtamudi estuary. Species of phytoplankton represented by diatoms, dinoflagellates and blue-green algae were observed from the estuaries. Diatoms formed the most abundant taxa throughout the study irrespective of seasons followed by Dinoflagellates and Blue-green algae. Maximum abundance of phytoplankton was observed during monsoon in Ashtamudi estuary and pre-monsoon in Cochin estuary. *Skeletonema costratum, Thalassiosira subtilis, Leptocylindrus danicus* and *Cyclotella meneghiniana* were the most abundant species observed during the study. High abundance of *Noctiluca scintillas* were noticed from the Ashtamudi estuary during the monsoon season. The study shows differential response of phytoplankton to the prevailing environmental conditions mainly due to the seasonal variability.

Comparatively high values of nutrients indicate that the productivity were more in Cochin estuary than that of Ashtamudi estuary. That may be a reason for relatively high plankton standing stock and abundance of phytoplankton in Cochin estuary. The seasonal variation in abundance as well as species composition of the phytoplankton was prominent in the Cochin as well as Ashtamudi estuary.

# Biodiversity and distribution of sponges (Phylum: Porifera) off Tuticorin, India

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Gulf of Mannar (GOM) is known for its luxuriant biodiversity of fauna and flora and a source of inspiration for research and innovations. Gulf of Mannar Biosphere Reserve (GOMBR) with an area of 10500 $km^2$ and having 21 islands of them, seven islands occurs in the Vaippar – Tuticorin area. Tuticorin area is characterized by the presence of hard rocky bottom, soft muddy bottom, lagoon and lakes. About 8-10 m depth zone from Thiruchendur to Tuticorin of GOM to a distance of 25 nautical miles from shore characterized by narrow belt of submerged dead coral blocks which serves as a very good substrate for sponges. Patches of coral ground "Paar" in the 16-23m depth zone with 10-16 nautical miles from land are place of pearl oyster beds (Mahadevan and Nagappan Nayar, 1967; Nagappan Nayar and Mahadevan, 1987) also forms a good habitat for sponges.

The sponges of Tuticorin have been considered to be the most diverse and abundant group due to the presence of unique ecological characters of the coast (Thomas, 1971; 1986). The sponge samples were collected from Mottagopuram (8°49'43.74"N & 78°10'5.89"E), Vellapatti (8°51'27.14"N & 78°10'3.67"E), Sippikulam (8°59'40.13"N & 78°15'12.39"E), Tharuvaikulam (8°53'20.02"N & 78°10'29.75"E ), Inigonagar (8°48'55.80"N & 78°9'48.66" E ), Hare Island (8°46'34.54"N & 78°9'56.88"E), Pattinamaruthur (8°55'12.41"N & 78°11'10.65"E), Harbour Beach (8°44'38.46"N & 78°10'20.35"E ), Kayalpattinam (8°35'7.25"N & 79°08'7.57"E), Veerapandiyapattinam (8°57'44.99"N & 78°13'7.10"E), Alanthalai (8°46'49.57"N & 78°10'07.17"E ), Kulasekharapattinam (8°39'36.1"N & 78°05'76.43"E), Manappad (8°37'82.44"N & 78°05'78.33"E) and Periathalai (8°33'36.64"N & 77°97'20.30"E) under the AICOPTAX project of MoEF & CC. During September 2018 and May 2019, a total of 293 sponge samples were collected by handpicking, snorkeling and SCUBA diving from the shore as well as sea. The sponges entangled in gillnet were also collected and preserved. A checklist of sponges reported from Tuticorin area was prepared and presented.

Systematic database regarding morphology, colour, spicules, and skeletal structures are prepared for species identification of the samples using standard monographs. Important species reported in the present observation are *Aulospongus tabulatus* (Bowerbank, 1873), *Axinella donnani* (Bowerbank, 1873), *Callyspongia (Euplacella) communis* (Carter, 1881), *Iotrochota sp, Clathria (Thalysias) procera* (Ridley, 1884), *Clathria (Clathria) indica* Dendy, 1889, *Mycale (Mycale) grandis* Gray, 1867, *Zygomycale parishii* (Bowerbank, 1875), *Phyllospongia sp, Spongionella sp., Suberites sp., Xestospongia testudinaria* (Lamarck, 1815), *Spongionella nigra* Dendy, 1889, *Pachychalina sp., Amphimedon subcylindrica* (Dendy, 1905) and *Stylissa carteri* (Dendy, 1889).

The detailed systematic account of the sponge species such as *Callyspongia (Callyspongia) ramosa* (Gray, 1843), *Amphimedon delicatula* (Dendy, 1889), *Neopetrosia similis* (Ridley & Dendy, 1886), *Stylissa carteri* (Dendy, 1889), *Lissodendoryx (Ectyodoryx) lissostyla* (Thomas, 1970), *Hymedesmia (Hymedesmia) mannarensis* Thomas, 1970, *Hymedesmia (Hymedesmia) stylophora* Thomas, 1970, *Clathria (Thalysias) vulpina* (Lamarck, 1814), *Clathria frondifera* (Bowerbank, 1875), *Clathria (Microciona) rhopalophora* (Hentschel, 1912) *Microciona rhopalophora, Axinella donnani* (Bowerbank, 1873), *Halina plicata* (Schmidt, 1868), *Plakina monolopha* (Schultze,1830), *Poecillastra schulzii* (Sollas, 1886) *Fasciospongia anomala* (Dendy, 1889), *Dysidea fragilis* (Montago,1814), *Dendrilla cactus* (Bergquist, 1961), *Dendrilla nigra* (Dendy, 1889) *and Dwarvinella mulleri* (Schultzei,1865) were done during the present study.

Sponges are known for its multifold ecological goods and services. Commercial utilization of sponges for several purposes including extraction of bioactive components is the major provisioning service provided by sponges. Its regulatory services include the filtration of water through canal system which regulates water quality of an area. It supports several other organisms as a source of habitat and place for living and protection.

# Sedimentary characteristics and macro-benthic community distribution in the coastal water off Kochi – a winter monsoon scenario

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Benthic community analysis paves the way for understanding different environmental factors affecting the productivity of the coastal ecosystem. In the present study, benthic community structure in the coastal waters off Kochi up to a 100 m depth profile from six sampling stations was evaluated during winter monsoon (December – February) along with sedimentary nutrients and biochemical composition of organic matter. Samples were collected monthly, between the latitude 9°57'59.5"N -9°54'30.4"N and longitude 76°11'7.04E-75°38'50.3E over three months. Among the different macro-benthic groups, gastropods (fig 1) were found to be dominant with a contribution of 51.8 %, followed by polychaetes (26.79%), crustaceans (18.11%) and nematodes (13.25%). Muddy coastal areas showed a less macrobenthic abundance. From coastal to offshore, sediment grains acquired sandy nature and harbours more functional macro-benthic groups and had the maximum oxygen consumption. The benthic trophic structure was found to be a function of salinity, where surface deposit feeders like nematodes and crustaceans showed a positive correlation to salinity. Nematodes and crustaceans showed a positive correlation indicating the same food source. The distribution of gastropod was found to be negatively correlated to bottom water dissolved oxygen (r =0.6). The biochemical composition of sedimentary organic matter (OM) and sedimentary nutrients was estimated spectrophotometrically. Among the biochemical compounds, protein was found to be high followed by carbohydrate and lipid. Protein to carbohydrate ratio was always >1 indicating a eutrophic to hypertrophic nature of sampling stations and provides a good habitat for benthic organisms.

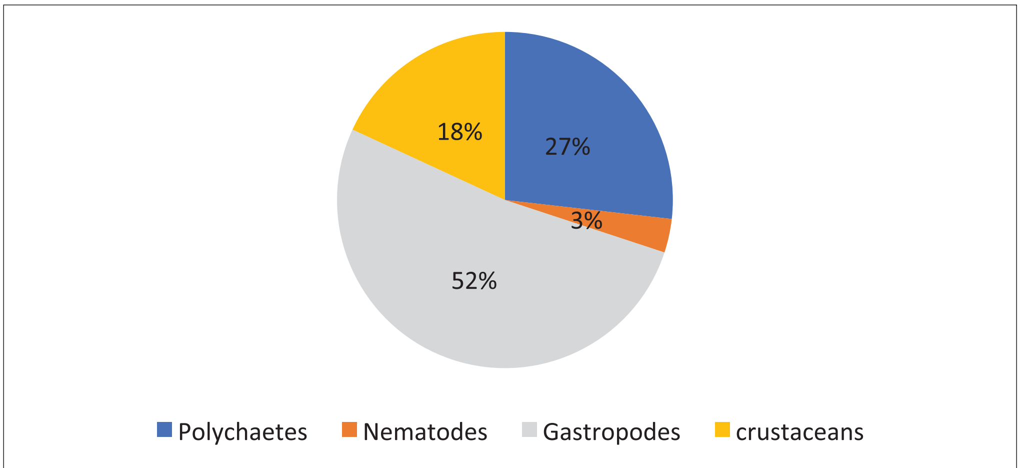


Fig.1. Distribution of macro-benthic community

# Economic valuation of coastal ecosystems in Odisha with special reference to fisheries

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The State of Odisha lying between latitudes 17.75°N–22.5°N and longitudes 81.5°E–87.6°E is bordered by the Bay of Bengal in the east and has coastline of 480 km forming 8% of the coastline of India. The state has 13 districts, of which four are coastal viz., Balasore, Cuttack, Puri and Ganjam. The continental shelf up to 200 m depth covers an area of 25,000 sq. km, which is 4.5% of the total area of the country's continental shelf. In the northern part of Odisha, the continental shelf extends up to 120 km and in the southern part up to 40 km. South Odisha comprising Ganjam, Puri and the southern part of Cuttack District, has narrow continental shelf and open sandy beaches, whereas northern Odisha, comprising central and northern Cuttack districts and Balasore is characterized by an extended continental shelf, intertidal flats and extensive river deltas. Odisha has a moderate climate, consisting of three seasons, summer from March to May, rainy season from June to September-November, and winter from December to February. Of the two monsoons, the active one is the South-West (S.W.), during June-September, and the weak is the North- East (N. E.) in November. The commercial fisheries revenues and costs were calculated following the World Resources Institute Fisheries Valuation Tool (WRI, 2007). Commercial fisheries data work sheets were developed as per the species list and landing data for the period 2010-2014 provided by Fisheries Resources Assessment Division (FRAD) and market price data provided by the Socio Economic Evaluation and Technology Transfer Division (SEETTD) of ICAR- Central Marine Fisheries Research Institute (ICAR-CMFRI).

Ecosystem services provided by marine and coastal ecosystem fall into four groups such as Provisioning services, Regulating services, Cultural and Recreational services and Supporting services. Bombay duck (*Harpadon nehereus)* shows discontinuous distribution and abundant along Odisha coast. Anchovy (*Coilia ramacarti*) is an endemic species to Odisha coast. Other high valued species include *Pampus argenteus* (Silver pomfret), *Pampus chinensis* (Chinese pomfret) and *Parastromateus niger* (Black pomfret) which are abundant and fetch high value as provisioning services. Seer fish fishery is supported by *Scomberomorus commerson, S. gutttus* and *Acanthocybium solandri*, considered to be high value fishes. Important marine fishes as provisioning services are Bombay duck, Sciaenids, Perches, Pomfrets, Tunas, Penaeid shrimps, Elasmobranchs, Hilsa, Catfishes, Eels, Lizard fish, Silverbellies, Ribbon fishes, Carangids and Seer fishes. Bhitarkanika mangrove (65000 ha) and Chilka lagoon (116500 ha) are the two important biodiversity sensitive areas coming under Ramsar site. Gahirmatha marine wildlife sanctuary which is the world's biggest nesting ground for an Olive Ridely turtle in the state has an area of 1435 km$^2$. Living fossil, mangrove horseshoe crab (*Carcinoscorpius rotundicauda*) and the Indo-Pacific horseshoe crab (*Tachypleus gigas*) occurs along the Odisha coast. Horse shoe crabs are used by traditional healers in the form of a liquified substance for curing joint pains.

The rich biodiversity of the state is supported by various ecosystems like mangrove (23395 ha), lagoon (89023 ha), reservoir (189972 ha), river and canals (223522 ha), flood plain (180000 ha), brackish water (430000 ha), tanks and ponds (123000 ha), continental shelf (2500000 ha), estuary (4000 ha), mudflat (25514 ha) and seashore (6046 ha). Using the Fisheries valuation tool of WRI, the total economic values of provisioning services provided by the fisheries resources were estimated as ₹14831 million (2010); ₹32770 (2011); ₹21533 (2012); ₹12026 (2013) and ₹14865 (2014). The monetary value of ecosystem services of ecosystems estimated using value transfer technology are mangrove (₹206816 million), lagoon (₹117400 million), reservoir (₹222492 million), river and canals (₹127544 million), flood plain (₹1591238 million) brackish water (₹503608 million), tanks and ponds (₹70185 million), continental shelf (₹253336 million), estuary (₹5275 million), mudflat (₹2585 million) and seashore (₹149 million). The high biodiversity value obtained is justifies the Bhitarkanika mangrove, Chilka lagoon, Gahirmatha marine sanctuary for the conservation of biodiversity.

# Reef building hard coral and associated fish diversity in the nearshore waters of Androth Island, Lakshadweep

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Androth is the largest Island in the Lakshadweep group which covers an area of 4.83 km$^2$. The Island occupies the whole interior of the atoll. It has a landmass in the East-West orientation with no lagoon. The present paper deals with the reef-building hard corals along with reef fish diversity assessment studies carried out in the nearshore waters of Androth Island.



Underwater survey and sampling were carried out in Androth during December 2016 for geo-referenced mapping of the distribution and diversity of hard corals and associated fish fauna. Diversity and distribution of coral were more in the reef flat all around Island followed by shallow areas with the exception on the north-eastern side. The depth ranges from 2 to 8 meters and 0.5 to 2.0 meters at north eastern and western part. The intertidal areas around the 'Moola' have many recruits of different massive and sub-massive corals which often got exposed during the low tide. The present study recorded 71 species of hard corals including two non-scleractinian corals *Heliopora coerulea* and Millepora *platyphylla* under 30 genera belonging to 14 families. An earlier study by CMFRI listed only 17 species under 9 genera from Androth Island including the non-scleractinians. In terms of family-wise diversity Acroporidae (4 genera & 21 species) dominates followed by Merulinidae. In terms of species diversity, the genus *Acropora* (16 species) and *Porites* (5 species) dominates followed by 4 species each in *Platygyra, Favites,* and *Pocillopora*; other genera are represented by less than three species in terms of numbers. The shallow intertidal area of the western side reef flat was dominated by several recruits of massive/sub-massive species from the genera *Porites*¸ *Dipsastrea Favites*, *Platygyra,* and *Galaxea.* Branching forms like *Pociilopora*, *Acropora*, and solitary genus *Fungia* was also abundant in this area. North-eastern side also recorded similar pattern in the species composition dominated by the massive/ sub-massive genera *Porites*, followed by *Favites*, *Platygyra, Galaxea* and *Pocillopora*. In deeper areas, in addition to the above-listed corals, the foliaceous *Echinopora lamellose*, non-scleractinian *Millepora platyphyllia* and *Heliopora coerulea* were also recorded.

The biodiversity analysis was performed using the PRIMER 6 software and the Brillouin index (HB) measures the diversity of corals within the recorded family and the estimated value was higher for Merulinidae (0.58) followed by Acroporidae (0.49). However, the Simpson index (lambda) was found to be higher in Acroporidae (0.73) which gives information on the dominance of species and this data was supplemented by Pieou's evenness or equitability, J' which recorded a lower value of 0.63 confirming the less evenness within the diversity hard coral species in Androth Island. SIMPER revealed that the cumulative species contribution (90.24 %) was mainly by the six families viz., Acroporidae, Merulinidae, Poritidae, Pocilloporidae, Agariciidae and Coscinaraeidae with an average dissimilarity of 40.59%.

A comparative paucity of reef fishes observed among the *Heliopora* compared to *Acropora* community. Reef fishes were identified up to species level from photographs and video graphs taken during the underwater survey. In Androth only 36 species of fishes were recorded representing 3 orders (13 family & 22 genera) and the family Pomacentridae (4 genera & 9 species) dominates followed by Acanthuridae (3 genera & 7 species), and Labridae (3 genera & 5 species) and others represented less than 3 in numbers. Bleaching, infestation by algae and encrusting sponges were noticed in *Acropora* and *Porites* colonies and also in different brain corals. Disease conditions such as pinking and ulcerative syndrome in *Porites* spp. and *Fungia* sp., tissue loss and white band disease in *Acropora* spp., damage due to trematodiasis, infestation by feather duster worms and predation by giant clam *Tridacna* sp. were noticed. Large scale bleaching and ulceration were recorded in *Pavona* sp. large scale tissue loss and necrotic patches were also observed in blue coral *Heliopora coerulea.*

# Zooxanthellate Jellyfishes with special emphasis on *Cassiopea andromeda* and *Mastigias papua* from Gulf of Mannar, Southeast Coast of India

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The global proliferation of marine jellyfish has become a major scientific interest due to its ecological role and socio-economic impacts. Symbiotic relationships are common in both the terrestrial and marine domains for sustaining species populations at ecosystem level. Cnidarians (mainly corals, sea anemones and jellyfish) live in a symbiotic relationship with zooxanthellae (photosynthetic dinoflagellates) in their tissues. Apart from the zooxanthellate algae, jellyfish exhibit a symbiotic relationship with different species of vertebrate particularly finfishes and invertebrates like crustaceans, cephalopods, and sea stars. Amongst Scyphozoan jellyfishes, symbiotic relationships with zooxanthellae were mostly reported in both Discomedusae (Rhizostomeae genera *Cassiopea, Mastigias*, *Phyllorhiza, Cotylorhiza*, *Rhizostoma* and Semaeostomeae genera *Aurelia* and Coronamedusae (Coronatae genera *Linuche*).

Investigation of symbiotic zooxanthellate jellyfish was carried during the peak swarming season from the years 2015 to 2018 by fixing jellyfish swarming focal points viz., Keelavipar to Sippikulam and Mottagopuram to Karapad Bay in Thoothukudi coast, Gulf of Mannar. Fortnightly net-sampling and visual observations were done. Two species of zooxanthellate jellyfish *viz.*, upside-down jellyfish *Cassiopea andromeda* (Forsskal, 1775) and golden spotted jellyfish *Mastigias papua* (Lesson, 1830) has been documented during the study period. Individuals of zooxanthellate jellyfish are collected, photographed fresh then observed for colour and zooxanthellae. The study revealed that inter-annual variability in the dominance of zooxanthellate medusae during the peak swarming season wherein the dominance of *C. andromeda* was found during the year 2015 & 2016 and *M. papua* dominance was more in 2017 & 2018. There were significant inverse relationships in the dominance of the two species. The major

| Diagnostics characters | *C. andromeda* (N=60 nos) | *M. papua* (N=72 nos) |
|---|---|---|
| Bell | Flat, disk-shaped | Dome-shaped with golden spots |
| Bell diameter | 30 to 150 mm | 35 to 130 mm |
| Oral-arms | 8; with tree like side-branches | 8; with club like appendages |
| Length oral-arms | 15 to 30.5 mm | 40 to 45.5 mm |
| Number of rhopalia | 16 to 19 | 8 |
| Velar lappets per octant | 8 | 8 |
| Colour forms | Dark brown & light brown | Brown & white |
| Weight | 4 to 120 g | 10 to 240 g |
| Habitat | Sea grass beds (muddy bottom) | Sea grass beds |
| Zooxanthellae | Oral arms, sub-umbrella & tentacles | Oral arms & sub-umbrella |

observed diagnostics characters are given in the above table

The study gives an insight on the zooxanthellate jellyfish with detailed diagnostic characters; however, there is a need for the molecular evidence to explain the cryptic nature of different species in the genera of *Cassiopea* and *Mastigas*. Understanding the jellyfish algal symbiosis is the need of the hour as the susceptibility of the symbiont is mainly depends on the temperature and other oceanological conditions. In addition, asexual reproduction planuloid forms between the two species are to be studied for arriving at the inter-annual variability. The observation provides baseline information for future research on the unexplored area specifically on zooxanthellate jellyfish algal symbiosis from Indian waters.

# An assessment of the taxonomy and diversity of Bothids (Bothidae: Pleuronectiformes) in India

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The majority of flatfishes inhabiting the Indo-Pacific region, are relatively small fishes and generally not of much commercial importance; taxonomic and ecological data are available only on limited fishes. Flatfishes captured in tropical fisheries are very often merely identified as "Pleuronectiformes", (Munroe, 2014) much information on the species is not undertaken. Therefore many new species are lost unnoticed in the catch. The Order Pleuronectiformes comprises of a highly distinctive group with bilaterally symmetrical larvae and highly asymmetrical, strongly compressed adults with a flat eyeless or blind side and a convex eyed side with both eyes protruding above the body surface allowing the fish to see even when lying buried in the sand.

Flatfishes in the family Bothidae are commonly called lefteye flounders. These fishes are most diverse in the tropical Indo-west Pacific, where species occur from the east coast of Africa and Red Sea throughout the Indian Ocean and the Indo – Australian Archipelago, Japan, Australia and New Zealand and across the Central Pacific (Norman, 1934). Bothids are characterized by an oval dorso-ventrally flattened body with sinistral eyes in most species, preopercle margin free and distinct, mouth terminal with lower jaw more or less prominent. Pelvic fin base on the ocular side is longer than that of the blind side and placed on the mid ventral line of the body, its origin well in front of the pelvic fin base on the blind side. Pectoral and pelvic fin rays are not branched, spines absent. Nasal organ is present on blind side near dorsal profile. Spines are absent on fins; dorsal fin origin is above or anterior to upper eye. Dorsal and anal fins is separate from caudal fin. Branchiostegal membranes are united and anus is placed on blind side.

A detailed survey was conducted along the Indian coastline during the period 2004-2010

| Genus | Species | New records |
|---|---|---|
| *Arnoglossus* | 2 | *Arnoglossus aspilos* (Bleeker, 1851) Spotless eye flounder |
| *Parabothus* | 1 | |
| *Bothus* | 3 | |
| *Chascanopsetta* | 1 | *Chascanopsetta lugubris*<br>New record from the west coast of India |
| *Crossorhombus* | 1 | |
| *Engyprosopon* | 2 | *Engyprosopon maldivensis* (Regan, 1908)<br>Olive wide eyed flounder<br>*Engyprosopon mogkii* (Bleeker, 1834) |
| *Grammatobothus* | 1 | *Grammatobothus polyopthalmus* |
| *Laeops* | 2 | *Laeops natalensis* Norman, 1931<br>Khaki flounder<br>*Laeops parviceps* Gunther, 1880<br>Small head flounder |
| *Neolaeops* | 2 | *Neolaeops micropthalmus* (von Bonde, 1922)<br>Cross eyed flounder |

for flatfishes of India. Morphomeristic studies was done as per Nair (2011) and identification done using standard textbooks. Of the 23 genera and 140 species reported worldwide (Fricke *et al.,* 2019), 9 genera and 16 species have been collected in the present study. The study revealed the presence of 7 new bothid records from Indian waters both from shallow and deep seas. Deep sea samples were from Andaman waters and deep sea shrimp trawlers operating off Northern Arabian waters. Most of them were extended distributions from the Indo -Australian belts and deep sea forms which had not been accounted earlier. Though earlier workers (Biju Kumar and Deepthi, 2009; Radhamanyamma, 1988) have listed species of Pleuronectiformes from Kerala coast, no such extensive information on these bothids is available. This is the first detailed biodiversity report on the shallow and deep sea bothids in Indian waters.

With the IUCN Abu Dhabi Call for Global Species Conservation Action (2019) for massively scaling up species conservation action in response to the escalating biodiversity crisis it is an urgent requirement that conservation status of threatened species is brought out with a view to bringing about widespread recovery by 2050. Biodiversity registers with the present status of the resource are a must in the present context. Species distributions, diversity and present status are to be mapped for all species whether they are commercially important or not for this to happen.

# Valuation of ecosystem services in the marine and coastal areas of West Bengal

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West Bengal lying between latitudes 21.5°N–24.5°N and longitudes 86°E–89°E is situated in the northern part of Bay of Bengal; between the state of Odisha in the south and Bangladesh in the east. The state with an area of 87,853 sq. km accounts for 2.6% of the geographical area of India. There are 16 districts of which two are coastal. The coastal districts are Midnapore and 24 Parganas which together have a coastline of 65 km, forming 1% of the coastline of India.

Data pertaining to valuation of marine and coastal ecosystems, such as population details, number of fishing crafts and gears, area of different coastal ecosystems, fish catch details and ecosystem services for different coastal districts along the state of West Bengal were collected. The commercial fisheries revenues and costs were calculated following the World Resources Institute Fisheries Valuation Tool (WRI, 2007). Commercial fisheries data work sheets were developed as per the species list and landing data for the period 2010-2014 provided by Fisheries Resources Assessment Division (FRAD) and market price data provided by Socio Economic Evaluation and Technology Transfer Division (SEETTD) of ICAR- Central Marine Fisheries Research Institute (ICAR-CMFRI). Standard methods and equations were followed for the valuation of ecosystem services. Value transfer methodology is important as it can be used very quickly to estimate the economic values associated with different services. The basic frame work for value transfer methodology includes five steps as described by Troy and Wilson (2006).

Ecosystem services provided by marine and coastal ecosystem fall in to four groups such as Provisioning services, Regulating services, Cultural and recreational services and Supporting services. Hilsa shad (*Hilsa ilisha*) is the most important species for West Bengal. Bombay duck (*Harpadon nehereus*) shows discontinuous distribution and abundant along West Bengal coast. Golden anchovy (*Coilia ramacarati*) is an endemic species to West Bengal coast. Another high valued species includes *Pampus argenteus* (Silver pomfret), *Pampus chinensis* (Chinese pomfret) and *Parastromateus niger* (Black pomfret) which are abundant and fetches high value as provisioning services. Seer fish fishery is supported by *Scomberomorus commerson*, *S. guttatus*, *Acanthocybium solandri* and considered to be high value fishes.

West Bengal has the largest brackishwater culture potential. It has been estimated that there is about 200,000 ha of water area, out of which 85,000 ha has been already found suitable for culture. At present, about 35,000 ha have been brought under cultivation, materializing about 40%. This also represents 75% of the total area cultivated in the whole of India. The state has got 2 Ramsar sites namely Sundarban reserve forest (4260 sq. km) and East Calcutta wetlands (12500 ha). The rich biodiversity of the state is supported by various ecosystems like mangroves (209330 ha), reservoirs (22672 ha), river and canals (559192 ha), flood plains (42000 ha), brackish waters (200000 ha), tanks and ponds (276000 ha), continental shelf (2000000 ha), estuary (185000 ha), mudflats (2726 ha) and seashores (3338 ha).

Using the Fisheries valuation tool of WRI, the total economic values of provisioning services provided by the fisheries resources was estimated as ₹16870 million (2010); ₹19283 (2011); ₹15391 (2012); ₹19715 million (2013) and ₹6844 million (2014). The monetary value of ecosystem services of ecosystem using value transfer technology are mangrove (₹1850521 million), reservoir (₹26553 million), river and canals (₹319080 million), flood plain (371289 million) brackish water (₹234236 million), tanks and ponds (₹157488 million), continental shelf (₹202668 million), estuary (₹243962 million), mudflat (₹276 million), and seashore (₹82 million). Biodiversity valuation is important to fulfill the critical national objective of creating growth in income and employment. Alteration and damage of ecosystem leads to loss of ecosystem services which ultimately affect the well-being of human beings.

# Diversity of zooplankton in selected water bodies of Cochin, Kerala

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Both water and zooplankton samples were collected from 7 stations viz. Puthuvypu canal (station 1), Cochin barmouth (station 2) Mangrove pond at Panambukadu (station 3), Panchayath pond at Panambukadu (station 4), Temple pond at Panambukadu (station 5), Vembanadu kayal (station 6) and Perumbadappu kayal (station 7) on weekly intervals during the period from February 2017 to June 2017. Different Physico- chemical characteristics in each station were recorded. A total of 28 groups of zooplankton were recorded from the study area. Out of the 28 groups, a maximum of 24 groups were recorded from station 2. The density of zooplankton was maximum at Station 4 (42459 per $m^3$) followed by station 5 (42120 per $m^3$), station 2 (6985 per $m^3$), station 1 (1837 per $m^3$), station 6 (1420 per $m^3$), station7 (925 per $m^3$) and station 3 (148 per $m^3$). Copepods dominated in all the stations and the maximum of 87% copepod was recorded in station 2. The data was analysed using PRIMER v.6 and all the biodiversity indices like Shannon-Wiener index, Simpson index, Species richness and evenness were calculated to compare the zooplankton between stations. Maximum diversity, species richness and evenness of zooplankton were recorded at station 3 followed by station 2 during the study period. Similarity in species composition between stations was studied by calculating the Bray-Curtis coefficient. The similarity was maximum between Station 4 and station 5 while it was minimum between station 3 and station 5. The distribution and abundance of zooplankton in different stations are described and discussed.

# Short-term variability in the macrobenthic abundance and community structure in the near shore waters of off Kochi with special emphasis on polychaetes

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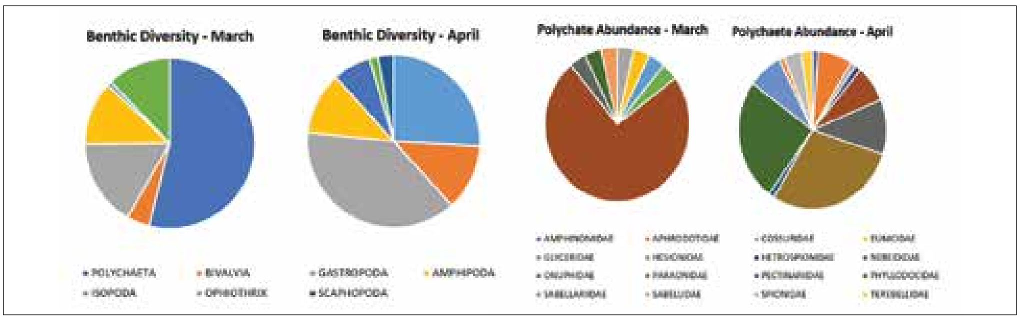
Benthos are sessile organisms living on the ocean floor either as epifauna, attached on the substratum or as infauna, burrowing within the substratum. Macrobenthic community structure is often influenced by physico-chemical factors such as salinity, organic content, sediment texture and by biological factors like food availability, prey-predator relationship and recruitments. The present study is aimed to understand the short-term variability in the macro-benthic community structure of the near shore waters of Off Kochi during two consecutive months of the pre-monsoon season and to identify the determining factors regulating their distribution between the two periods. Sampling was carried out at varying depths (5m, 10m, and 20m) for two consecutive months of the pre-monsoon season. Macrobenthic community and the sediment samples were collected using a Van-Veen grab ($0.0756m^2$). Sediment characteristics such as the organic carbon content, texture, salinity and redox potential were analysed along with the detailed taxonomic identification of the macro benthic community. In general, the macrobenthic abundance (1759 organisms/$m^2$) and diversity (7 taxa) was observed to be maximum at 5m depth during April whereas it was minimum at 20m depth (251 organisms/$m^2$ and 3 taxa respectively) during March. Polychaeta formed the predominant macro benthic taxa followed by Gastropoda and Bivalvia. Contribution of bivalves and gastropods to the benthic community varied with the changes in the sediment texture. The detailed taxonomic analysis of the polychaete community revealed a shift in the community composition from deposit feeders (43.7%) to carnivores (45.8%) with the changes in the sediment texture between the two periods. The present study depicting the short-term variability in the macrobenthic community structure of the near shore waters of Off Kochi reveals a significant change in their abundance and community composition and indicates sediment texture having a crucial role in governing the macro benthic distribution and community structure.



# Phytoplankton distribution in estuarine and coastal waters of Mumbai

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Ecosystem biodiversity includes phytoplankton, zooplankton, Benthos, sea weeds and mangroves in the coastal region of the country. One of the most studied ecosystems is Thane creek adjoining Karanja creek towards Uran-Mandve villages side - Vasai creek and coastal waters of Mumbai. Coastal water receives approximately 1800 MLD of sewage water which it terms affect assimilative capacity water. The phytoplankton distribution study was conducted during three seasons viz. premonsoon, winter and postmonsoon season 2007-08. Maxmium phytoplankton biomass 27900/L (TC8W-premonsoon), 18180/L (TC9W-winter) and 104000/L (TC6W-postmonsoon) was observed in estuarine waters. Phytoplankton species *Klebsormidium* sp., *Navicula* sp., *Nitzschia* sp., *Thalassiothrix* sp., *Coscinodiscus* sp., *Gyrosigma* sp. were the freshwater, salinity tolerant and marine water species dominant in estuarine and coastal waters. Moderate values of Shannon weiner Diversity index were observed in surface waters of estuary and coastal water. Simpson index of dominance had shown inverse relationship i.e the index decreases in estuarine water during high tide though the dominated phytoplankton species belong to marine phytoplankton. Eutrophication leads to dominance of *Klebsormidium* sp. (Chlorophyceae) in estuarine water from sampling stations 1 to 10 (East, Center, West of the sampling stations). Phytoplankton 19 species, 18 species and 27 species and diatoms as dominant flora were observed at 16 sampling stations of 4 transects in coastal waters (nearshore, 1km, 3km, and 5km distance from shore). Scatter digram of phytoplankton species distribution in coastal water and two way ANOVA had shown seasonal variation of phytoplankton in coastal waters.

# Biodiversity value of ecosystem services along the Goa -Daman & Diu coast

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Goa has an area of 3,702 km$^2$ and lies between latitudes 14°53' 54" N-15°40'00"N and longitudes 73°40' 33" E-74°20'13" E. The state has a unique place in the Indian history and bears a long cultural and geographical heritage. Blessed with presence of seven rivers, western Ghat Mountains, two estuaries, coral islands and estuarine islands. The state forms one of the richest biodiversity hotspot of India. Fisheries, the most important provisioning service provided by the varieties of ecosystems along with tourism and cultural services forms the backbone of Goan Economy. The commercial fisheries revenues and costs were calculated following the World Resources Institute, Fisheries Valuation Tool (WRI, 2007). Value transfer methodology was used to estimate the economic values associated with different services as per Troy and Wilson (2006).

Ecosystem services provided by marine and coastal ecosystems fall into four groups such as Provisioning services, Regulating services, Cultural and Recreational services and Supporting services. The provisioning services include the fish as food, commercial fisheries, fish processing, local fisheries, aquaculture, raw material for industries, bioactive compounds. Major regulating services are gas regulation, water regulation and habitat protection. Cultural and recreational services include beach tourism, spiritual services, heritage value, education and research. Major drivers of the reduction in the ecosystem services are anthropogenic and natural impacts, land use change, habitat loss, invasive species, pollution, eutrophication and climate change.

## Goa

There were 2,189 fishermen families in the state, with a population of 10,545. The number of families in South Goa and North Goa were 1,388 and 801 respectively. There were 2,370 active fishermen of whom 1,505 were full time fishermen and 865 were part-time. The rich biodiversity of the state is supported by various ecosystems like mangroves (1752 ha), reservoirs (2363 ha), river and canals (9362 ha), tanks and ponds (396 ha), continental shelf (100000 ha), saltpans (2929 ha), estuaries (8000 ha), mudflats (3286 ha) and seashores (519 ha). Using the Fisheries valuation tool of WRI, the total economic values of provisioning services provided by the fisheries resources were estimated as ₹5005 million (2010); ₹2719 (2011); ₹2514 (2012); ₹5052 million (2013) and ₹7436 million (2014). The monetary value of ecosystem services of ecosystems using value transfer technology are mangroves as 16045 million, reservoirs as ₹2914million, river and canals as ₹5559 million, tanks and ponds as ₹1712 million, continental shelf as₹105813 million, saltpans as ₹607 million, estuaries as₹11868 million, mudflats as ₹440 million and seashores as ₹18 million.

## Daman and Diu

Daman and Diu have two districts and a Union Territory of India. There are 11 marine fishing villages spread along the coast of Union Territory of Daman and Diu with 6 villages in Daman and 5 in Diu. The total number of marine fish landing centers was 5, of which two were located in Daman and three in Diu. There were 7,374 fishermen families in the Union Territory with a population of 40,016. The number of families in Daman was 1,584 and Diu was 5,790. There were 7,480 active fishermen of whom 6,042 were full time fishermen, 1,339 part-time and the rest engaged in fish seed collection.

Using the Fisheries valuation tool of WRI, the total economic values of provisioning services provided by the fisheries resources were estimated as ₹651 million (2010); ₹2528 (2011); ₹4046 (2012); ₹4443 million (2013) and ₹3570 million (2014). The monetary value of ecosystem services estimated using value transfer technology are mangrove as ₹557 million, lagoon ₹32 million, reservoir as ₹146 million, river and canals as ₹217 million, tanks and ponds as ₹50 million, continental shelf as₹101334 million, salt pan as ₹13 million, estuary as ₹1319 million, mudflat as ₹107 million, and seashore as ₹5 million. The Economy of Goa and Daman Diu is directly related to the four ecosystem services.

# Microhabitat preference and distribution pattern of tidepool Sponges from Veraval coast, Gujarat

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In the present study, rocky tide pools of the south Saurashtra coast at Veraval (20˚54'N, 70˚22'E) were surveyed for sponge diversity, microhabitat assessment and the assemblage structure. Visual survey and random quadrat method was used for this study. A total of 10 intertidal sponge species (*Cliona laticavicola, Clinachyrella alloclada, Callyspongia diffusa, Halichondria panacea, Haliclona cinerea, Haliclona tubifera*, *Cliona aprica*, *Halichondria melanodocia* and *Cliona* sp.) belonging to five families were observed. A total of fifteen microhabitats were surveyed in the rocky tidepools, and the following habitat types were scored for their presence-absence at the rocky shore. Those were platform, crevices, caves, rock pool, coral pool, boulder area, cobble or sand area etc. which are supporting the diversity and distribution of tide pool sponge. The results indicated that the sponges prefer specific micro habitats like underneath of rock, rock pool, coral pool etc. In the coral assemblage, the sponges distributed clustery in the middle and lower intertidal zone while, in case of zoanthid assemblage, the sponges were randomly distributed in upper and middle intertidal zone. This may be due to different ecological environment, physical and biological attributes. It was evident that influence of attributes like water depth, pool structure and assemblage structure change the sponge structure, diversity and distribution within the micro habitat.

# Economic valuation of fishery resources of Maharashtra coast

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Maharashtra with a coast line of 720 km with 153 landing centres situated in the five coastal districts namely, Thane, Greater Bombay, Raigad, Ratnagiri and Sindhudurg. The state, which has a continental shelf of 89,096 Km2, offers rich potential for marine fisheries. The areas of potential fishing grounds in 0-50 m depth and 50-200 m depth are 2.55 and 10.48 million hectares respectively. Fishing takes place almost throughout the year except during the monsoon period. Several types of boats, mechanised and non-mechanised, using different gears land their catches. Bombay duck, non-penaeid prawns, penaeid prawns, croakers, pomfrets, elasmobranchs, perches and ribbonfishes are some of the commercially important groups which form the bulk of landings.

Commercial fisheries data work sheets have developed as per the species list and landing data for the period 2010-2014 provided by FRAD and market price data provided by SEETD of CMFRI. Standard methods and equations were followed for the valuation of ecosystem services. The basic frame work for value transfer methodology includes five steps as described by Troy and Wilson (2006).

Ecosystem services provided by marine and coastal ecosystem fall into four groups such as Provisioning services, regulating services, Cultural and recreational services and Supporting services. Cultural and recreational services include beach tourism, ecotourism, boating, spiritual services, heritage value, education and research. Supporting services include nutrient cycling, habitat for migratory and resident species of fish, birds, marine mammal and reptiles. Major drivers of the reduction in the ecosystem services are the anthropogenic and natural impacts, land use change, habitat loss, over exploitation of fisheries, invasive species, water pollution, industrial pollution, sewage, eutrophication, fragmentation of water bodies and climate change.

Bombay duck (*Harpadon nehereus)* shows discontinuous distribution and is abundant along Maharashtra coast. The Golden anchovy (*Coilia dussumieri*) is an endemic species to Maharashtra. Among seerfishes spotted seerfish (*Scomberomorus guttatus*) dominates in the fishery. Two important croaker species in the fishery are Koth (*Otolithoides biaurites*) and Ghol (*Protonibea diacanthus*) which grows to large size and fetches a high market price. Another high valued species includes Silver pomfret (*Pampus argenteus*), Chinese pomfret (*Pampus chinensis*) and Black pomfret (*Parastromateus niger*) which are abundant and fetches a high value as provisioning services. Among crustaceans, penaeid prawns such as *Penaeus indicus, P. monodon, P. canaliculatus, P. stylifera, Metapeneus dobsoni, M. monoceros, M. stridulans* contribute to the biodiversity value of the inshore ecosystem. The non-penaeid prawns like *Acetes indicus*, *Nematopalaemon tenuipes*, *Exhipploysmata ensirostris* and *Acetes johni* are important resources. The state has one protected area - Malvan (marine) Wildlife Sanctuary (30 Km$^2$).

The rich biodiversity of the state is supported by various ecosystems like mangrove (30238 ha), reservoir (368135 ha), river and canals (299730 ha), brackish water (12000 ha), tanks and ponds (72000 ha), continental shelf (8909600 ha), saltpan (7025 ha), estuary (10000 ha), mudflat (22249 ha), creeks (41636 ha) and seashore (4873 ha).

Using the Fisheries valuation tool of WRI, the total economic values of provisioning services provided by the fisheries resources was estimated as ₹20190 million (2010); ₹22448 (2011); ₹24700 (2012); ₹29194 million (2013) and ₹30323 million (2014). The monetary value of ecosystem services of ecosystems using value transfer technology were mangrove as ₹267310 million, reservoir as ₹431153 million, river and canals as ₹171029 million, brackish water as ₹14054 million, tanks and ponds as ₹41084 million, continental shelf as ₹902848 million, salt pan as ₹1424 million, estuary as ₹13187 million, mudflat as ₹2254 million, creeks as ₹4219 million and seashore as ₹120 million.

Economic valuation of Biodiversity gives an inference on the biodiversity loss, of marine and coastal ecosystems. The loss of biodiversity may adversely affect ecosystem services and human well-being, basic materials for life, human health and wealth, sustainability of the resources for the future generations, trade offs between conservation and national priorities, hence to be prevented by proper policy interventions.

# Mapping of seaweed and seagrass resources in Atolls of Lakshadweep Archipelago, Central Indian Ocean

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Seaweeds are macroalgae that are found attached to the substratum in benthic habitats. Macroalgae are multicellular, autotrophic and photosynthetic plants which are contributing significantly to the primary productivity of the marine ecosystem. This article deliberates the mapping of seaweed and sea grass resources in 10 inhabited Islands of Lakshadweep atolls. The assemblage of seaweeds in various geomorphologic zones was mapped with the help of underwater surveys. The maximum number of seaweeds was observed in intertidal zones and lagoons of the atolls with the record of 57 species of seaweeds, and five species of seagrasses. The species *Padina pavonica* displayed the dominance in most of the atoll reef, assemblage pattern of the species *Boergessenia forbessi* shown remarkable pattern across the different geomorphological zones of these atolls. Natural and anthropogenic threats to the seaweed and seagrass resources in these atolls are highlighted in the present study for better management options for ecosystem benefits.

# Sponge fauna of Kavaratti, Pitty and Chetlat Islands of Lakshadweep

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Lakshadweep Islands lying between Lat. 8°13' N and Long 71°74' E includes 10 inhabited and 17 uninhabited Islands. Pioneering work on sponge fauna of Lakshadweep was done by Gardiner (1903-1906). Later, Thomas (1973, 1979) recorded 41 species of sponges from Minicoy including the coral and shell boring species such as *Spirastrella cuspidifera, S. inconstans* and *Cliona spp*. Sponge samples for the present study were collected during March-October 2019 from Pitty (10°50'22.4"N & 72°37'38.95"E), Chetlat (11°41'25.20"N & 72°42'05.49"E) and Kavaratti islands (10°33'36.25"N &72°37'19"E) using handpicking, snorkeling, SCUBA diving and preserved. Spicules were prepared by boiling separately small pieces of sponges in con. $HNO_3$ and Sodium hypochlorite. They were passed through 3 changes of distilled water and absolute alcohol series. The spicules were dried and mounted on a glass slide using mounting medium DPX.

The species identified in the present study were *Spongia (Spongia) officinalis* Linnaeus, 1759, *Haliclona (Gellius) fibulata* (Schmidt, 1862), *Hyrtios erectus* (Keller, 1889), *Hyattella cribriformis* (Hyatt, 1877), *Phyllospongia (Carteriospongia) foliascens* (Pallas, 1766), *Fasciospongia cavernosa* (Schmidt, 1862), *Dysidea fragilis* (Montagu, 1814), *Psammaplysilla purpurea* (Carter, 1880), *Haliclona (Haliclona) oculata* (Linnaeus, 1759), *Iotrochota baculifera* Ridley, 1884, *Gelliodes fibulata* (Carter, 1881), *Sigmadocia fibulata* (Schmidt, 1862), *Zyzzya fuliginosa* (Carter, 1879), *Callyspongia (Cladochalina) diffusa* (Ridley, 1884), *Callyspongia (Cladochalina) diffusa* (Ridley, 1884), *Echinodictyum longistylum* Thomas, 1968, *Agelas mauritiana* (Carter, 1883), *Myxilla (Ectyomyxilla) arenaria* Dendy, 1905, *Echinoclathria rimosa* (Ridley, 1884), *Clathria (Thalysias) reinwardti* Vosmaer, 1880, *Mycale (Mycale) grandis* Gray, 1867, *Mycale (Zygomycale) parishii* (Bowerbank, 1875), *Spirastrella coccinea* (Duchassaing & Michelotti, 1864), *Cervicornia cuspidifera* (Lamarck, 1815), *Spheciospongia inconstans* (Dendy, 1887), *Suberites carnosus* (Johnston, 1842), *Terpios cruciatus* (Dendy, 1905), *Siphonodictyon minutum* (Thomas, 1972), *Cliona celata* Grant, 1826, *Pione vastifica* (Hancock, 1849), *Cliona viridis* (Schmidt, 1862), *Jaspis penetrans* (Carter, 1880), *Tethya robusta* (Bowerbank, 1873) and *Ecionemia acervus* Bowerbank, 1862.

According to Thomas (1989), it is interesting to note that the bath sponge *Spongia officinalis* is very common in these islands. In the order Poecilosclerida, only two genera of the family Phorbasidae-*Echinodictyum* Ridley and *Damiriana* D'laubenfels were represented at Lakshadweep. So far the only species represented in the genus *Echinodictyum* was *E. longistylum* Thomas. Under the division Myxiliformis the species such as *Ophlitaspongia rimosa* (Ridley), *Clathria reinwardti* (Vosmaer), *Mycale grantis* (Gray) and *Zygomycale parishii* (Bowerbank) are present. The earlier comparison of sponge fauna of Lakshadweep with the other zoogeographical regions such as Atlantic ocean, Mediterranean Sea, Red Sea, Australian region, Pacific Ocean, Arctic and Antarctic region, they are related to Australian region (62%). Burton (1918) opined that the water currents are the major factor for the distribution of sponge fauna. Because of the closed nature of Indian Ocean, their similarities with other oceans are minimal.

# An assessment of the distribution and diversity of cardinal fishes in India

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Family Apogonidae are ray finned fishes, commonly called cardinal fishes. Most species live in tropical or subtropical waters, where they inhabit coral reefs and lagoons. They are distinguished by their large mouths and two separated dorsal fins, the first spine with 6-8 spines and the second with one spine and 8-14 soft rays (except *Paxton* sp. which has a continuous dorsal fin). Usually ctenoid scales are present. Anal fin has two spines and 8-18 soft rays. It is reported that some species of this family brood their eggs inside the mouths of the males, whereas in others it is only the females. Most species are nocturnal in habit, spending the day in dark crevices within the reef. They are generally small fishes and are often brightly coloured. Biggest fish reported has a TL of 20 cm while most fishes are less than 10 cm.

The family is represented by 380 valid species globally and 32 new species which have added in the period of 2010-2019 (Fricke *et al*., 2019). Jones and Kumaran (1980) reported 22 species from Lakshadweep Islands. Suresh and Thomas (2006) reported the occurrence of 24 species from the coastal waters of Neendakara to Cape Comorin adding 6 new species from Indian seas. Later, Rao (2009) reported 41 species and Rajan *et al*. (2013) reported 48 species from Andaman Island. Robert (2012) reported 5 species from south west of India. Saravanan *et al*. (2017) recorded 65 species from the Indian seas. Rajan Kumar *et al*. (2019) recorded 3 species from the North east Arabian Sea.

The present study reports on the diversity of family Apogonidae from the Indian waters including Lakshadweep and Andaman Islands which contains original collections, collections in museum and compilations from literature. 82 species belonging to 25 genera have been reported from India in the present work from Neendakara, Cochin and Vizhinjam (Kerala); Chennai, Gulf of Mannar and Tuticorin (Tamilnadu); Visakhapatnam (Andhra Pradesh); Gulf of Kachchh, Veraval and Mangrol (Gujarat), Digha (West Bengal), Chilka lagoon (Odisha), Lakshadweep and Andaman Islands from both East and Western coast of India. The original collection contains 8 species from the coast of Kerala, Tamilnadu and Andaman Islands. Taxonomic works were re-examined, literature was scanned critically to come to the present list. *Jaydia queketti* (Gilchrist, 1903) and *Holapogon maximus* (Boulenger 1888) reported from the Kerala coast, which have seldom reported from the Indian seas. *Ostorhinchus fasciatus* (Shaw 1790), *Sphaeramia orbicularis* (Cuvier 1828), *Ostorhinchus fleurieu* (Lacepede 1802) *Jaydia ellioti* (Day 1875) *Apogonichthyoides nigripinnis* (Cuvier 1828) and *Pristiapogon fraenatus* (Valenciennes 1832) are also included in the original collections. Most species have been recorded from the Lakshadweep and Andaman Islands as Apogonids are reef associated fishes. This study also validates the present status of species found in India as most of the species under genus *Apogon* have changed to genus *Ostorhinchus.*

The IUCN in 2019 has issued an urgent call to massively scale up species conservation action in response to the escalating biodiversity crisis. The Abu Dhabi Call for Global Species Conservation Action appeals to the world's governments, international agencies and the private sector to halt species decline and prevent human-driven extinctions by 2030, and to improve the conservation status of threatened species with a view to bringing about widespread recovery by 2050. Unless the biodiversity experts and scientists of the different countries across the world are ready with the present counts of the diversity of their fauna, extinctions leave alone decrease cannot be predicted.

# Structuring in white fish *Lactarius lactarius* along the Indian coast using mitochondrial ATPase 6/8 marker

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*Lactarius lactarius* (Linnaeus, 1758), white fish, is a monotypic genus and commercially important marine species, belonging to the Family Lactaridae. The False trevally is native to the Indian Ocean and distributed from East Africa to Southeast Asia and in the western Pacific Ocean from Japan to Queensland, Australia. It has a natural distribution across Indian waters. Genetic information on wild populations or the stock determination is detrimental for a sustainable and appropriate fisheries management. Though *L. lactarius* has high demand in coastal markets, there is no concerted study on the stocks and population structure from any of the Indian coasts. In the present study, population structure and genetic differentiation of *L. lactarius* in Indian waters were investigated using mitochondrial gene sequences and ATPase 6/8 genes (855 bp). 100 individuals were sampled from five localitions along the Indian coast, Mangalore, Cochin, Chennai, Visakapatanam and Digha, West Bengal. Sequence analysis of ATPase 6/8 gene revealed 39 haplotypes. High haplotype diversity (0.802) and low nucleotide diversity (0.00424) were observed. Demographic history analyzed using mismatch distribution appeared as unimodal. Tajima' D resulted in negative and non-significant (P>0.05) values, whereas Fu's Fs tests were negative and significant (P <0.05). The coefficient of genetic differentiation was significant (FST: 0.23) and AMOVA also indicated moderate and significant genetic differentiation between the west coast and the east coast, but no significant variations among the populations occurring along the same coast. The genetic stock structure revealed in this study will be helpful for stock specific management measures for conservation and management of *L. lactarius* in Indian waters.

# Total economic values of coastal habitats and fishery resources off Puducherry coast

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Puducherry has four coastal districts namely, Yanam, Puducherry, Karaikal and Mahe. There are 40 marine fishing villages wherein fishermen reside. The maximum number of fishing villages is in Puducherry district (17) and there is only one village in Mahe district. The number of fishing villages in the remaining districts is Yanam (12) and Karaikal (10). The total number of marine fish landing centres in Puducherry was 26, of which 16 belonged to Puducherry district. There were 14,271 fishermen families in the Union Territory with a population of 54,627. The maximum number of families was in Puducherry district (7,088) followed by Yanam (3,754). Among 14,271 fishermen families, 99.8% belonged to traditional fishermen. There were 12,209 active fishermen of whom 11,510 were full time fishermen, 668 were part-time and the rest was engaged in fish seed collection. There were 6,010 fisherfolk engaged in fishing allied activities, such as marketing (64%), labourers (20%), making/repairing net (6%), curing and processing (3%) and peeling (1%). here were 2,593 crafts in the fishery out of which 369 were mechanized, 1,562 motorized and non-motorized formed the rest. Almost 99% of the crafts in the mechanized sector were trawlers.

Data regarding biodiversity valuation such as population details, number of fishing crafts and gears, area of different coastal ecosystems, fish catch details and ecosystem services provided by different coastal and marine habitats for different coastal districts along Puducherry coast were collected. The commercial fisheries revenues and costs are calculated following the World Resources Institute, Fisheries Valuation Tool (WRI, 2007).

Ecosystem services provided by marine and coastal ecosystem fall in to four groups such as Provisioning services, regulating services, Cultural and recreational services and Supporting services. The provisioning services include the fish as food, commercial fisheries, fish processing, local fisheries, aquaculture, raw material for industries, bioactive compounds, wood products and agricultural products. Major regulating services such as gas regulation, water regulation, shoreline protection, creeks, rocky shores, mangroves, carbon sequestration and habitat protection. Cultural and recreational services include beach tourism, ecotourism, boating, spiritual services, heritage value, education and research. Supporting services include mangrove forest supports habitat for migratory and resident species of fish, birds, marine mammal and reptiles, nutrient regeneration. Major drivers of the reduction in the ecosystem services are the anthropogenic and natural impacts, land use change, habitat loss, over exploitation of fisheries, invasive species, pollution, eutrophication and climate change. Among these the Climate change and the introduction of invasive alien species are emphasized as the two direct drivers of alteration in marine and coastal ecosystems that are most difficult to inverse. Direct drivers in land use change and habitat loss are coastal development such as port construction, urbanization, tourism-related development, industrial sites, mangrove deforestation, mining of coral, sand, minerals, civil engineering works, coastal deforestation and aquaculture-related habitat conversion having direct negative impact on biodiversity

The rich biodiversity of the state is supported by various ecosystems like mangrove (285 ha), river and canals (2113 ha), flood plain (1000 ha), continental shelf (100000 ha), estuary (4000 ha), mudflat (505 ha), creeks (212 ha) and seashore (809 ha). Using the Fisheries valuation tool of WRI, the total economic values of provisioning services provided by the fisheries resources were estimated as ₹511 million (2010); ₹301 (2011); ₹1516 (2012); and ₹2946 million (2013). The monetary value of ecosystem services of ecosystems using value transfer technology are mangrove as ₹252 million, river and canals as ₹120 million, flood plains as ₹884 million, continental shelf as ₹1013 million, estuary ₹527 million, mudflat as ₹5 million, creeks as ₹2 million and seashore as ₹2 million. Biodiversity value of different ecosystems plays an important role in the future policy options for the development and conservation plans of Puducherry.

# Naturalization of *Artemia* in Indian subcontinent; molecular approach to delineate the diversity

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Among the different live feeds, *Artemia* are extensively used as the starter diet in Indian larviculture industry since 1980s mainly using imported strains due to the lack of nutritional quality and optimum nauplii size of indigenous parthenogenetic Artemia even though autochthonous parthenogentic Artemia populations have been reported from Indian hypersaline habitats since 1950s. To assess the present status of the Artemia populations and the possibility of invasion by the introduced *A. franciscana* in Indian Salinas, an extensive study was conducted using conventional and molecular approaches. *Artemia* samples were collected from North West (Mithapur & Nanganvadi), South West (Tamaraikkulam & Tuticorin) and South East (Kelambakam & Marakkanam) regions. Internally Transcribed Spacer-1 (ITS1) from the Indian population was PCR amplified and sequenced. The ITS-1 sequence of the Indian *Artemia* populations exhibited 99% homology with the exotic *Artemia franciscana*. The mean pair-wise genetic distances between the Indian *Artemia* populations were negligible, indicating their genetic similarity. The absence of any significant genetic distance values between Indian *Artemia* populations and *A. franciscana* confirms that they are conspecific. Phylogenetic analysis grouped all the Indian *Artemia* populations with *A. franciscana* species. Principal Coordinate Analysis (PCoA) clearly grouped the Indian *Artemia* populations and the reference strain of *A. franciscana* in to a single cluster. While the remaining new world species viz, *A. persimilis*, *A. salina* and *A. sinica* were grouped into another clade, the old world *A. persimilis* stood alone separately. Widespread import and use of alien *A. franciscana* as live feed in hatcheries must have paved the way for its massive invasion followed by the displacement of *A. parthenogenetica* from the Indian hyper-saline habitats. Lack of regional endemism in populations of distant origins was evident, indicating that the invaded populations have naturalized and are in the process of evolution. This forms the first report of invasion by *A. franciscana* in hypersaline habitats of Indian subcontinent.

# The economics of ecosystems and biodiversity value of Gujarat coast

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Gujarat, the northern most maritime state of India with a coastal length of 1600 Km has 12 districts namely Valsad, Navasari, Surat, Bharuch, Anand, Bhavnagar, Amreli, Junagadh, Porbander, Jamnagar, Rajkot and Kutch. The state receives less south west monsoon followed by a coastal upwelling, but heavy runoff from the Sabarmadhi, Tapthi and Narmadha results in enrichments of inshore areas which promotes growth of commercially important fishes such as Bombay duck, Pomfret, C*roakers*, Threadfins and Prawns. The state has Gulf of Kutch Marine National Park (270 $km^2$) and one Ramsar site, The Nalsarovar Bird Sanctuary (120.82 $km^2$).

Commercial fisheries data work sheets have developed as per the species list and landing data for the period 2010-2014 provided by Fisheries Resources Assessment Division (FRAD) and market price data provided by Socio Economic Evaluation and Technology Transfer Division (SEETTD) of ICAR- Central Marine Fisheries Research Institute (ICAR-CMFRI). Methodological framework for the valuation provides step by step process to calculate provisioning services, regulatory services, supporting services and cultural services by calculating the value of food services, mangrove ecosystem, seagrass ecosystem, reef ecosystem, open ocean ecosystem and coastal ecosystem of Gujarat state. The purpose of the present paper is to estimate the values of ecosystem services along the coastal and marine areas using the Total Economic Value (TEV) and Value Transfer (VT). The commercial fisheries revenues and cost were calculated following the Fisheries Valuation Tool (WRI 2007) of the World Resources Institute.

Ecosystem services provided by marine and coastal ecosystem fall into four groups such as Provisioning services, regulating services, Cultural and recreational services and Supporting services. Supporting services include nutrient regeneration provided by the coral islands, Gulf of Kutch and Gulf of Khambat, Mangroves, estuaries, lagoons and creeks. Major drivers of the reduction in the ecosystem services are the anthropogenic and natural impacts, land use change, habitat loss, over exploitation of fisheries, invasive species, pollution, eutrophication and climate change.

Bombay duck (*Harpadon nehereus*) shows discontinuous distribution and is abundant along Gujarat coast. Golden anchovy (*Coilia dussumieri*) is an endemic species to Gujarat. Among seerfishes, the spotted seer fish (*Scomberomorus guttatus*) dominated in the fishery. Two important croaker species in the fishery are Goyani (*Otolithoides biaurites*) and Ghol (*Protonibea diacanthus)* grows into large size and fetches a high market price. Another high valued species includes Silver pomfret (*Pampus argenteus)*, Chinese pomfret (*Pampus chenensis)* and Black pomfret (*Parastromateus niger*) which are abundant and fetches high value and are included as provisioning services.

Among crustaceans penaeid prawns such as *Peneus indicus, P. monodon, P. canaliculatus, P. stylifera, Metapenaeus dobsoni, M. monoceros, M. stridulans* are contributing to the commercial and biodiversity value of the inshore ecosystem. The non-penaied like *Acetes indicus, Nematopalaemon tenuipes, Exhippolysmata ensirostris* and *Acetes johni* are also important resources. Three species of turtles Leather back (*Dermochelys coriacea*) green turtle (*Chelonia mydas* ) and Olive ridley turtle (*Leptidocheylus olivacea*) are found on the Gujarat coast. Sea cow (*Dugong dugon*) is also found.

Using the Fisheries Valuation Tool of WRI, the total economic values of provisioning services provided by the fisheries resources were estimated as ₹21825 million (2010); ₹21866 (2011); ₹22562 (2012); ₹28546 million (2013) and ₹32144 million (2014). The monetary value of ecosystem services of ecosystems using value transfer technology are mangrove as ₹799818 million, coral reef as ₹538909 million, lagoon as ₹29394 million, reservoir as ₹291600 million, river and canals as ₹157418 million, flood plain as 106082 million, brackish water as ₹117118 million, tanks and ponds as ₹157488 million, continental shelf as ₹1661882 million, salt pan as ₹18424million, estuary as₹249237 million, mudflat as ₹229052 million, creeks as ₹15190 million, salt marshes as ₹1275359 million and seashore as ₹160 million. The high values obtained in the present study justify the GOK Marine National Park and one Ramsar site Nalsarovar Bird Sanctuary for the conservation of species and habitat and the welfare of the human being.

# An exploratory study of diversity of marine fauna from bycatch of Puducherry coastal waters with special reference to Pisces, crustaceans and Echinoderms -Will it be a treasure or trash?

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Puducherry is a beach town, lies on the east coast of Tamil Nadu between 11°52 'N; 79°45'E and 11°59'N, 79°52'E located on the Coromandel Coast of the Bay of Bengal. It holds its own identity mark in marine resources. It supports a medley of animals in, on or nearly above the continental-shelf sea floors. Many of these animals are valued as seafood and most of the fishing deed ensued in this zone and 95% of marine fish catches come from continental shelves. However, modern fishing gear is not selective; it seldom catches only the target species. It is estimated that 27 million tonnes of bycatch were discarded globally each year. This high volume of discards and the increasing awareness of the potential impacts on the environment have resulted due to bycatch, becoming an issue of global importance. The problem of bycatch is recognised as one of the most pivotal conservation challenges associated with world's fisheries today, still no strong elucidations. The present study focussed on the diversity of marine fauna that are found in bycatch, both edible and non-edible, specifically on fishes, crustaceans and echinoderms. The study encompasses 10 landing centres namely M. Pudukuppam, Narambai, Panithittu, Nallavadu, Veerampattinam, Solai Nagar, Pilllaichavadi, Pudukuppam, Chinnakalapet and Periakalapet, for a month (November, 2019). This short period of study opened up a multitudinous of marine fauna which is unimaginable. A total of 105 species were recorded (Fig. 1), out of which 81 species are fish falls under 13 orders (Table. 1), 12 species of crustaceans under

Table: 1 Orderwise species numbers of Pisces

| Order | No.of species | % |
|---|---|---|
| Anguilliformes | 3 | 3.8 |
| Aulopiformes | 1 | 1.2 |
| Beloniformes | 2 | 2.5 |
| Scombriformes | 3 | 3.7 |
| Clupeiformes | 7 | 8.6 |
| Lophiformes | 1 | 1.2 |
| Myliobatiformes | 1 | 1.2 |
| Perciformes | 44 | 54.3 |
| Pleuronectiformes | 7 | 8.6 |
| Scorpaeniformes | 2 | 2.5 |
| Siluriformes | 3 | 3.7 |
| Syngnathiformes | 3 | 3.7 |
| Tetraodontiformes | 4 | 5 |

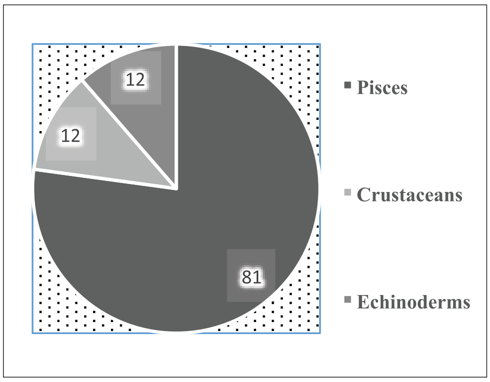


Fig. 1 No of species in by catch

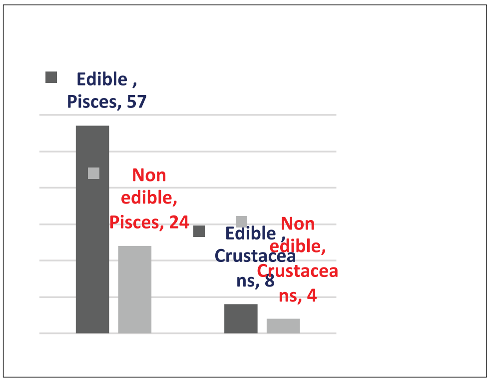


Fig. 2 No of edible and non edible species

two orders and 12 species of echinoderms under 6 order were recorded. Of these, 57 species of fishes and 8 species of crustaceans are edible, and 24 species of fishes, three species of crustaceans were non- edible (Fig .2). Echinoderms are completely considered as 'trash'. An interesting fact was found among 81 fish species, 40 species of fishes were associated with reef habitat. Demersal and reef associated species were found to be dominant groups in all the landings. During the study, some species show first distributional record in Puducherry, a rare crab species *Ranina ranina*, sea horses *Hippocampus kelloggi* and *Hippocampus kuda* that were regularly seen in 1 or 2 numbers, mantis shrimp *Lysiosquilla tredecemdentata*, spiny lobsters *Panulirus homarus* and *P. polyphagus*, heart sea urchins *Lovenia elongata* and *Maretia planulata* has been documented. Single species of sea cucumber and sea lily were also recorded but the species identity is not yet confirmed. This one month study threw a light on biodiversity including several level of species. Out of 105 species, 31 species were non edible that are thrown on the shore. Fishing needs to be brought under the scanner. Enforcement of bycatch reduction technologies along with mesh size regulations and fishing effort at sustainable levels will facilitate protection and restoration of marine biodiversity. In the present study, various approaches to minimise the bycatch and the impact of indiscriminate fishing operations on biodiversity are discussed.

# Benthic morphology of coral reefs of Suheli Par, an uninhabited island of Lakshadweep Archipelago

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Coral reefs around the world are under threat from both climatic and anthropogenic stressors. The studies specifically about the diversity of corals in the reefs have not been extensively conducted on the uninhabited island of Lakshadweep. The benthic status of Suheli par (10.068143 N 72.297196 E) located in the Arabian Sea, 30 nautical miles south-west of Kavaratti atoll of Lakshadweep, has been studied. The study was carried out during March 2019 using 26 line intercept transects on different geomorphological zonations, such as intertidal, Lagoon, Outer reef flat (5-8 m depth), and Outerreef slope (15-20 m depth). The results showed the occurrence of 44 species of live Scleractinian coral from the Suheli par constituting 22 genera under ten families. Each geomorphologic zone has a different pattern of abundance and coral assemblage. The present study reported dead coral with algae dominated the overall status of the reef (44.29%), sand (21.37%), rubble (19.32 %), and (15.02 %) of live coral. Evaluation and monitoring of the benthic status of coral reefs are required for scientific understanding and reef conservation initiatives. Hence, we brought out the status of the Suheli par, where there is no anthropogenic influence, has been documented so far. The database generated from the present study provides baseline information for the development of community reserve or marine protected area in this uninhabited atoll.

# Genetic cataloguing of Octopus species from coastal waters of Kerala using molecular markers

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Octopuses are one of the commercially important fishery resource form the Indian coast and there is a targeted fishery for octopus in many fish landing centres in Kerala. There are lot of taxonomic ambiguities within the octopus species and the accurate identification of species is of prior importance in conserving such vulnerable species. With a view to identify and genetically catalogue the octopus species of Kerala coast, specimens were collected from different landing centres of the region. Molecular characterization was done with partial sequence information of mitochondrial gene Cytochrome C oxidase-I (COI) gene. Total 17 specimens of 7 species were collected from 4 locations and COI sequences were generated (650 bp). 7 species included viz, three ocellate octopus, belonging to the genus *Amphioctopus*; (*Amphioctopus neglectus. A. marginatus* and *A. rex)*, two from genus *Cistopus: (Cistopus Indicus* and *C. taiwanicus)*, one each from *Octopus vulgaris* and *Callistoctopus macropus.* Both genus of *Cistopus* and *Amphioctopus* showed the intra and inter specific distance ranging from 0.0-1.0 % and 7.0-21.0 %, respectively. Phylogenetic analysis using maximum likelihood approach revealed that all the genera of the family Octopodidae are monophyletic.

# Diversity assessment of infraorders Brachyura, Anomura, Caridea and Gebiidea associated with mangroves in and around Mumbai

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Mangroves provide suitable habitat and food for the crustaceans and in turn these crustaceans make the substratum suitable for the mangroves to grow. An assessment of the crustacean diversity was conducted in the mangrove forests and mangrove mud flats of in and around Mumbai, Maharashtra, India. The samples were collected from September 2018 to December 2019 during the low tide from different sites of Mumbai and its vicinity. The study revealed rich and diverse mangrove resources which harbor enormous diversity of flora and fauna. A total of 17 brachyuran crabs, 1 Anomuran crab, 1 caridea and 1 Gebiidea species were collected, of which, 7 species belonged to Sesarmidae, 3 species to Ocypodidae, 3 species to Grapsidae, 3 species to Portunidae, 1 species of Varunidae, 1 species of Alphiedae, 1 species to Thalassinidae, 1 species to Dogenidae. Sesarmid species were found climbing on trees and they are good example of mangrove herbivory. During low tide crabs would go into the burrows and climb the trees when high tide comes.

# Report of coral predation by crown of thorn starfish *Acanthaster planci* on Lakshadweep reefs

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Across the globe, coral communities on many reefs have been subject to major damage by Crown-of-thorn starfish *Acanthaster planci*. Destructive population outbreak of the COTs has devastated coral reefs throughout the Indo-Pacific for decades. But little is known about its presence on Lakshadweep reefs. In the face of ever -growing threat to coral reef ecosystems in Indo pacific and beyond, it is necessary to investigate the presence of this natural predator and its impacts on Lakshadweep reefs. Our study revealed the presence of *A. planci* on the lagoon reefs of Kavaratti and Chetlat Islands of Lakshadweep group of Islands in the Arabian Sea. We also found that *Acropora* are the most preferred prey spp of this dangerous predator on these reefs. Results of this study would benefit coral reef research to devise appropriate management strategy for the conservation of coral reefs in this region.

# The influence of habitat characteristics on the distribution of Acanthurids and Pomacentrids in South Andaman, India

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Documenting the patterns of distribution and diversity of species across environmental gradients has long been a main focus of ecology. In marine ecosystems, physical characteristics of a habitat exert a significant influence on the species distribution. The family Acanthuridae consists of tropical and subtropical reef fishes commonly called surgeonfishes, tangs and unicorn fishes and family Pomacentridae is represented by damselfishes and anemone fishes.

In the present study, the diversity and distribution of Acanthurids and Pomacentrids were analysed from September 2014 to August 2015 across 6 major reefs in South Andaman. Underwater Visual Census (UVC) was carried out through line transect method to assess the diversity and abundance. The fishes were identified using standard identification keys. Trophic diversity was ascertained by grouping the fishes into various dietary categories, based on the criteria for functional entities. Four major microhabitats were identified: Live Coral, Dead Coral, Macroalgae and Sand. The distribution percentage of each of these microhabitats in the reef was calculated after regular field visits.

The six habitats, viz. Chidiyatapu, Marina Park, North Bay, Wandoor, Havelock and Neil were highly varied with respect to anthropogenic influence, live coral cover, macroalgal distribution and general reef health. Chidiyatapu and Havelock have a high percentage of live coral cover. Marina Park has an artificial reef, formed by the boulders from a Sunken Swimming Pool. North Bay is a tourist area with no fishing, but the anthropogenic influence is high due to snorkelling, sea-walking and recreational boating. Wandoor reef is severely degraded, possibly due to the impact of Tsunami. Wandoor reef has a high percentage of macroalgae, dominated by *Sargassum sp*. and *Turbinaria sp*. Neil reef has a unique structural pattern, dominated by corals of *Heliopora sp.*

Statistical analyses were done in MS Excel and PRIMER V6. Square root transformation was performed to down weigh the abundant species and Clusters were produced using the transformed data, based on Bray Curtis similarity matrices. Principal Component Analysis was performed to ascertain the similarities among stations.

The results indicated that Havelock had the highest abundance of Acanthurids and Pomacentrids, while Wandoor had the least abundance of Acanthurids and Pomacentrids. While Chidiyatapu had the highest Shannon Wiener Index (1.78) and species richness (13.59), Wandoor had the highest evenness (0.98). Species diversity, species richness and phylogenetic diversity had a strong positive correlation with the percentage of live coral cover present in these stations. However, the live coral cover was negatively correlated with evenness. This is confirmed from previous studies which have shown that evenness and richness are negatively correlated.

Cluster diagram (Fig 1) revealed that while Neil, Marina Park and Wandoor were grouped together, the other stations with a higher coral cover were grouped together with respect to fish abundance. PCA plot revealed that the stations were grouped differently with respect to the trophic categories (Fig 2).

Six dietary categories were identified: browsers (feeders of macroalgae), corallivores (feeders of live coral polyps), farmers (species that guard a selected reef area and weed out unwanted algal species), grazers (feeders of turf algae and detritus), omnivores and planktivores (species that feed on plankton). Among these six trophic categories, planktivores were the most abundant. This could be due to their shoaling nature, due to which they swarm in huge numbers in the reef edge. All the dietary groups were positively correlated with the live coral cover percentage in the stations. Surprisingly, the macroalgal cover was negatively correlated with the browsers that feed on macroalgae. This emphasizes the importance of live coral cover for ichthyofauna. This paradox needs long term monitoring to identify the role played by herbivorous fishes in determining the algal cover. More comprehensive studies are recommended to ascertain the weighted influence of habitat characteristics on ichthyofaunal diversity.

With the worldwide concern regarding the phase shifts between coral and macroalgae, detailed long term studies of factors that influence ichthyofaunal diversity are needed to understand the role that the habitat plays in shaping the fish communities and vice versa.

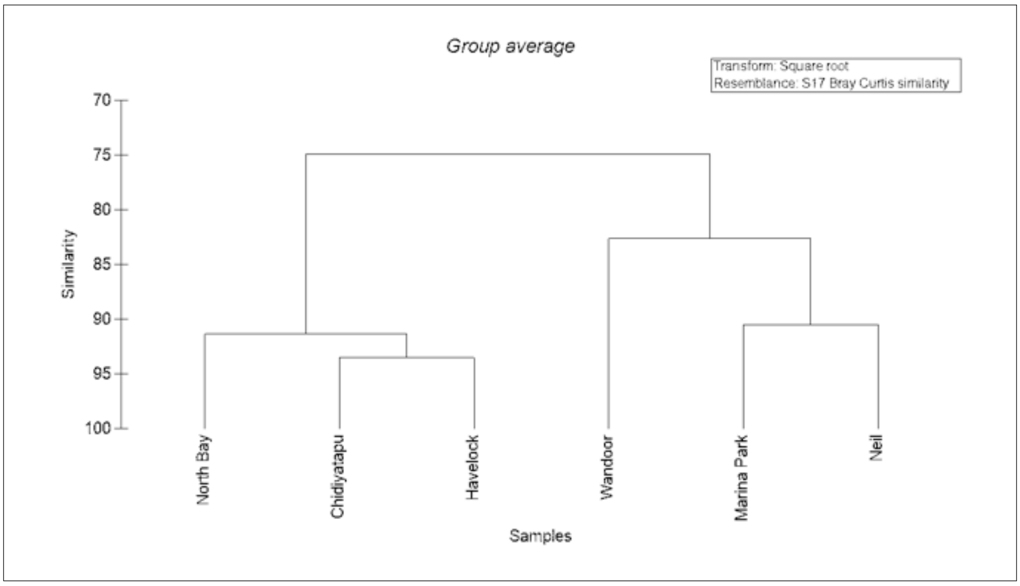


Fig 1: Dendrogram showing the grouping of stations based on the abundance of Acanthurids and Pomacentrids

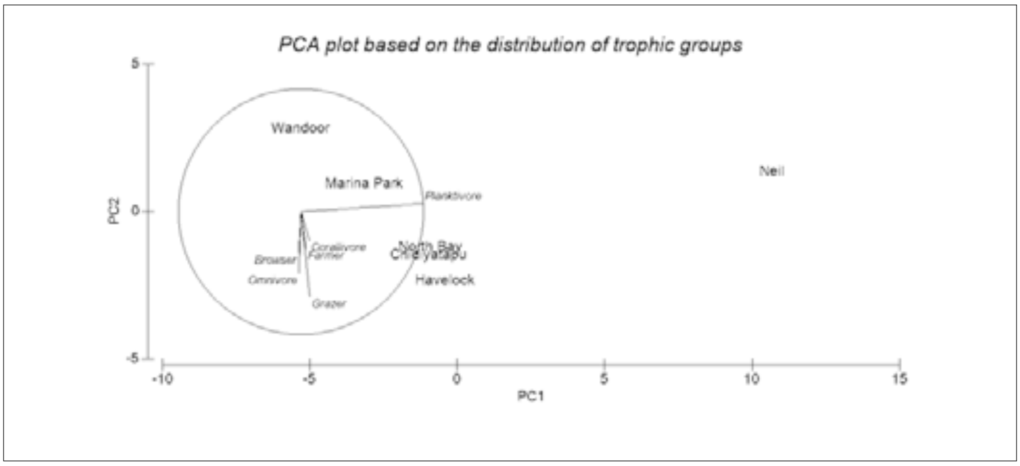


Fig 2. PCA plot indicating the grouping of stations based on trophic categories

# Restoration of degraded seagrass meadows with transplantation trials along Ramanathapuram coast, Tamil Nadu

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Seagrass meadows are one of the ecosystem engineers accountable for sustainability and higher productivity. Globally seagrass meadows are in recession due to pollution, anthropogenic interventions, herbivory and climate change. Rough estimates show that restoration of one hectare of seagrass would be equivalent to more than 10 ha of tropical forest restored. To standardize the protocol for restoring seagrass beds in degraded meadows, our attempts made off Soliakudy (9°42'485"N; 78° 59' 595"E) in Ramanathapurm district through transplantation trials are presented here.

Fresh plantlets of *Cymodocea serrulata* and *Syringodium isoetifolium* intact with roots and rhizome drifted to the beaches were collected in the morning hours and after cleaning the epiphytes and epifauna the saplings were transplanted the same day using three types of substrata. Weekly observations were made to record the specific growth rate, density and percentage of survival and the results are discussed in the light of habitat restoration and ecosystem development.

# Diversity of Sea cucumbers in Kavaratti Atoll, Lakshadweep Archipelago

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Echinoderms are functional components of tropical fauna and play a crucial functional role in coral reefs. However, their diversity remains not documented as that of other reef organisms such as corals or fish. A general understanding of the diversity and population size of Sea cucumbers is still lacking from Indian waters. We reviewed current knowledge of the diversity of the class Holothuroidea in Kavaratti atoll of Lakshadweep Archipelago. The study was conducted from October to December 2017 with 43 belt transects from intertidal zones, lagoon, outer reef flat, and outer reef slope to a depth of 30m. Twenty-one species have been identified, two species of the Genus *Bohadschia* are new records for the island. The family Holothuridae, which includes the largest and most diverse taxa in this atoll, comprise of 14 species. Three species each of Synaptidae and Stichopodidae and a single species of Labidodematidae constitute the assemblage of sea cucumbers. The study discusses geomorphologic factors and habitat characteristics influencing the patterns of diversity and abundance of sea cucumbers, which would form a preliminary reference database for the region for developing further conservation strategies. The recent increase in the number of species recorded has resulted from intensive sampling efforts by the use of the latest techniques. The impact of climate change, global warming, and ocean acidification on biodiversity loss could be assessed through long term monitoring programmes. The variability in holothurians diversity, especially in regions like Kavaratti atoll, where, conservation of this fauna requires special attention as the region exposed to frequent anthropogenic interventions

# Icthyodiversity of stake-net fishery of Cochin backwaters

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The Cochin backwaters are one of the primary openings of the Vembanad Lake into the Arabian Sea. The estuarine region closer to the sea is known for its traditional prawn fishery by traditional set nets viz., Chinese dipnet and the Stake net. Stake net is a conical bagnet set against the tidal currents by means of wooden stakes. Even though shrimps are the target resources for stake nets, a significant component of the catch is various finfish species including juveniles and undersized individuals. In order to evaluate the diversity of the finfish component in the stake net catches and to assess the magnitude of exploitation of juvenile finfish by the gear, a study was conducted for a period of nine months from June 2018 to March 2019, during which fortnightly samples of fishes were collected from landings from stake nets operated across two sampling stations of Cochin backwaters. A total of 95 species belonging to 13 orders and 51 families were recorded from the stake nets fish landings operated from the two selected stations of during the study period. Of these 35 species were found to be of commercial importance. The order Perciformes had the highest representation (56 species). The fish fauna was dominated by Gobidae family followed by Carangidae and Leiognathidae.17 % of the fishes were pure marine, 4 % were fresh water, 5% of the fishes are found in either brackish or marine habitat and 9% of the species are found in either freshwater or brackish water habitat. The IUCN redlist status of the fishes recorded showed that out of the 95 species of finfishes, 52% belonged to the least concern (LC) category, 38% of species were under Non evaluated and 7% were under Data Deficient (DD). All major parameters of diversity were worked for the finfishes appearing in the stake net landings. Seasonal observations on fish diversity revealed that the higher numbers of species were recorded during post monsoon season. Considering the diversity richness of the area, the frequent occurrence of undersized fish in stake net catches in sizeable quantities need to be taken care of by the authorities, by way of strict implementation of regulations.

# An insight into the taxonomy and population biology of some fishes of the Family Cynoglossidae (Teleostei: Pleuronectiformes)

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Family Cynoglossidae commonly called Tongue soles are highly specialized fishes of Order Pleuronectiformes (Heterosomata) with about 161 valid species (Fricke *et al*., 2019); majority of the species are marine, showing higher diversity of distribution in tropical waters (Norman,1934). These fishes contribute about 5% of the total demersal fish catch. Fishery is contributed by halibuts, flounders and soles; of the three main groups, soles contribute to the major commercial fishery. Of the soles, the Malabar sole, *Cynoglossus macrostomus* alone contributes to more than 90% of the flatfish landing. The taxonomic history reveals that Norman (1928) described 91 species of flatfishes from Indian waters whereas Menon (1977) described 49 species including a new species. Radhamanyamma (1988) recorded 25 species of flatfishes belonging to five families from the south-west coast of India. Later Biju Kumar and Deepthi (2009) recorded 7 species of Cynoglossidae along the Kerala coast which was updated by Nair and Gopalakrishnan (2012) with 12 species in 2 genera.

The flatfish fishery mainly dominated by sole fishery especially the Malabar sole, *Cynoglossus macrostomus*. The biology and population parameters were estimated using Forese and Binohlan (2000) equation for the asymptotic length ($L_\infty$), natural mortality (M) and annual growth rate (K). The taxonomic details of the species have been generated by using the previous published information. Growth parameters of the selected species *Cynoglossus macrostomus* (Malabar sole) the most dominant species in the fishery was estimated using FiSAT. The $L_\infty$, K, M values of *Cynoglossus macrostomus* was found to be 177.2 mm, 0.64 and 1.54. The exploitation rate E was found to be 0.6, which is a good exploitation rate, the fishery is therefore sustainable.

Without a strong taxonomic database on the various organisms inhabiting the ecosystem, issues pertaining to sustainable utilization (capture fishery), and biodiversity conservation and management cannot be effectively addressed. The flatfish resources require more attention as these are a mixture of highly valuable table fish as well as an export item. A study on the diversity of the flatfishes available in the Indian waters is a requisite for successful management of the fishery as well as accurate documentation and maintenance of biodiversity.

# Seasonal varitation of zooplankton community structure in the near shore waters of Kochi, Kerala

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The coastal waters of Kerala are important fishing grounds of major pelagic fishes like mackerel and anchovy. Zooplankters are important food of these fishes. Apart from this, the near shore areas act as nursery for several fin fishes and shell fishes where the food of the larvae and juveniles is mostly zooplankton. Potential of pelagic fishery ie. fin fishes, crustaceans, mollusks, and marine mammals either directly or indirectly depends on zooplankton. Due to their large density, short life span, drifting nature, high species density and different tolerance to stress, they are being used as the indicator organism for physical, chemical and biological process in the aquatic system. Zooplankton plays an important role in the marine food chain as an intermediate link between phytoplankton and fish. A study was conducted in the coastal waters off Cochin (between Lat. 9°58'34" & 10°00'15 N and Long 76°14'108 & 76° 02'05"E) with the objective to assess the seasonal variation and the related zooplankton diversity. Quantitative and qualitative studies on zooplankton help in understanding the fishery potential of the area and reflect the health of ecosystem.

The Seasonal variations in zooplankton biomass, composition and diversity in different depth stratum (5, 10, 20 and 30m) were studied during 2011 to 2015. Zooplankton samples were collected by vertical hauls from different depth zones using standard net of mesh size of 200µm. Twenty groups of zooplankton were recorded from the study area. The biomass varied from (0.00521 mlm$^{-3}$ to 0. 0.89825 mlm$^{-3}$) during pre-monsoon. The maximum zooplankton biomass was observed during monsoon (0.00040 mlm$^{-3}$ to 1.38843 ml m$^{-3}$). The biomass during post monsoon varied between 0.00952 ml m$^{-3}$ to 0.19982 ml m$^{-3}$. The composition of zooplankton groups showed a diverse seasonal variation. This variation can be attributed to their competition within the community for survival and environmental characters. The major groups in the zooplankton community were amphipods, chaetognaths, copepods, cladocera, fish eggs, fish larvae, decapods, *Lucifer* sp., polychaetes, siphonophores, pteropods and ostracods. Among different groups of zooplankton, copepods were dominant followed by cladocera during premonsoon. During monsoon, cladocera was dominant group. The dominant groups observed during post monsoon were copepods (41.57%) followed by cladocera (21.21%) and fish eggs (14.33%). However the decapod biomass was high in upper layer during premonsoon and decreased with increase in depth. During 2015, density of fish eggs was more in January and February at 5m and 10m depth. Density of fish larvae was highest at 5m depth in April. The study indicated that the ecosystem has rich zooplankton biomass which can support the primary carnivores. This is one of the reasons for the sustained fishery of planktivores fishes in this region.

# By-catch of marine mammals in India

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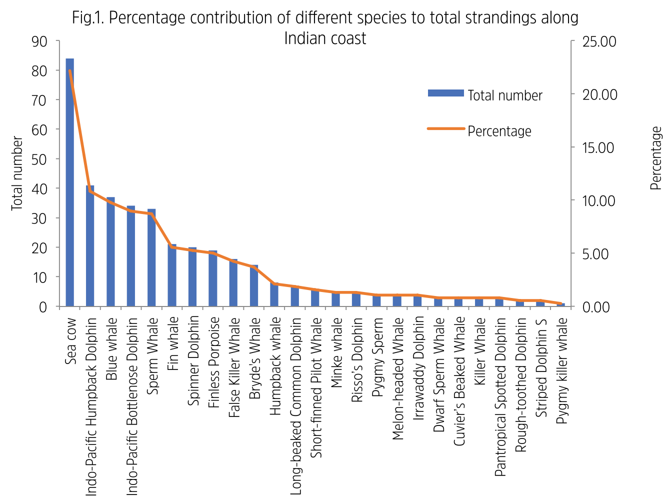
All the 27 species of marine mammals in the Indian seas are protected under Wildlife (Protection) Act 1972. While the Act has significantly reduced intentional capture of marine mammals, incidental capture in fishing gears is still a cause for concern. Records on entanglement of marine mammals in fishing gears were collected and analysed. It was observed that gill nets are responsible for 98.8% of the mortalities. Occasional reports on incidental catch / entanglement in trawl, purse seine, shore seine and long line has also been recorded. This became a problem from 1970s though the first report in 1953 was that of an incidental catch of porpoise in a dol net along Gujarat. A total of 45 porpoises have been found to be caught by fishing nets along Karnataka (34nos), Kerala (9nos; from gill nets) and one each from Gujarat (dol net) and Tamil Nadu (gill net). Of the 34 nos. from Karnataka, 32 were from gill net and 2 from purse seines. Surveys conducted in Kerala and Karnataka indicate that the porpoises continue to get entangled in gill nets in Karnataka and though this creates problem for the fishermen whose nets get torn, they release them back to the sea most often. From 1976 to 2013, about 766 entanglements / incidental catch of dolphins in fishing gears has been reported from Karnataka, Kerala, Tamil Nadu and Andhra Pradesh. Seven species of dolphins, such as Spinner Dolphin (275nos), Long-beaked Common Dolphin (237 nos.), Indo-Pacific Bottlenose Dolphin (177 nos.), Indo-Pacific Humpback Dolphin (64nos.), Rough-toothed Dolphin (8 nos.), Risso's Dolphin (4 nos.) and Pantropical Spotted Dolphin (1 no) were reported in the fishing gear related mortality along the Indian coast (Fig 1).

Spinner Dolphins were reported in all the four south Indian states while others were mostly caught along the Kerala -Tamil Nadu fishing gear operations. Highest fishing related mortality was reported from Kerala (526 nos.) followed by Tamil Nadu (231 nos.). In Karnataka, fishing related mortality was low (2 nos); spinner dolphin and Indo Pacific



humpback dolphin one each. Only one species has been reported from Andhra Pradesh Spinner dolphin (5 nos.) and from A& N Islands, beaked common dolphin has been reported. During this century, the number of dolphin species reported in fishing related mortality reduced to four; only species such as Risso's Dolphin, Spinner Dolphin, Indo Pacific humpback dolphin Pantropical spotted dolphin have been reported. Entanglement of porpoises has been reported from Karnataka and Gujarat during this century. In Kerala, information on incidental catch of cetaceans in fishing gears from major landing centres like Munambam, Chavakkad, and Ponnai, landing centre were collected. One finless porpoise and 2 Indo-Pacific Humpbacked dolphins was reported to be entangled during the period. From Karnataka, monitoring was done at Mangalore fishing harbour which is one of the major fishing centres, where incidental catch of marine mammal is reported to land at regular interval. A total of 12 individuals of three species namely *Neophocaena phocaenoides, Stenella longirostris* and *Sousa plumbea* were observed as incidental bycatch landing in this centre. Gillnet is the major gear for incidental catch, as in other parts of India followed by purse seine. Surveys conducted among fishermen have indicated that they feel that dolphin population has increased and this has negatively affected their fishing activities. Damage to gear and expenses to mend this is a problem cited by gill netters of south India. Fishermen from southwest coast of India have suggested that culling of dolphins should be done to avoid damage to nets.

# Stranding of marine mammals in India

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Marine mammals play an important role in shaping the behaviour and life history traits of prey species and predators, in nutrient storage and recycling, and in modifying benthic habitats. All the 27 species of marine mammals in the Indian seas are protected under Wildlife (Protection) Act 1972. For developing conservation measure, it is imperative to have knowledge on the distribution and abundance of the targeted resource. Sine marine mammal stock cannot be made using methods for other marine resources; stranding records are used as an indirect means to monitor the status, distribution, seasonal and abundance of marine mammals. The records of the stranded marine mammals along the Indian coast were collected and the data analysed. It was found that 25 species consisting of 5 baleen whales, 4 toothed whales, 14 dolphins and one each of finless porpoise and sea cow have been reported during the 216 year period from 1800 to 2016. The number of stranding records was only 21 during the period 1800 to 1889 while it increased to 243 in the succeeding century and during the 16 years since 2000, 115 stranding have been reported. Poor means of communication and low accessibility to coastal regions may be the reason for low stranding records during the 19$^{th}$ century. The stranding rate which was low, 0.2 per year increased to 2.4 per year in 20$^{th}$ century and currently the rate is 7.2 per year. This is alarming and urgent measures have to be taken to prevent and control this. Since these are records of stranding being reported, the actual number of animals stranded is much higher, since in some cases it is mass stranding and that of mother and calf. Among the five groups highest stranding was of dolphins (39%) followed by baleen whales (23%), sea cow (22%), toothed whales (11%) and finless porpoise (5%). Highest stranding of all groups was in Tamil Nadu. The stranding of baleen whales was high in all the maritime times along west coast except Goa, while along east coast (except Tamil Nadu), the stranding records were low. Stranding of toothed whales was highest, slightly more than 50% along Tamil Nadu coast followed by Lakshadweep Islands (16%). They were absent in Goa, Orissa and West Bengal.

Dolphin stranding was reported all along the Indian coast except Lakshadweep Islands and was highest in Tamil Nadu (41%), followed by Kerala (20%). Porpoise stranding was reported from all the states along west coast except Goa. Along Kerala and Karnataka, almost same number of reports on Porpoise stranding has been observed (16% each). Along east coast, apart from Tamil Nadu (53%), stranding was not observed in other maritime states except in Orissa. Stranding of porpoises was not observed in the Island territories. Dugong stranding was observed only from states which have sea grass habitats; Tamil Nadu (79%), Gujarat (14%) and A&N islands (7%). Stranding were more along the east coast (58%) than the west coast (36%) and comparatively higher in A& N islands than Lakshadweep group of Islands. The southeast and southwest coasts have more stranding than other regions. The stranding along East coast was found to be higher during December and January while along the west coast it was during Feb, April and September. Among the maritime states, Tamil Nadu recorded the highest stranding 179 records (47%) followed by Kerala (13%) and Karnataka (7%). Maharashtra and Gujarat had higher stranding than other states of east coast - Andhra Pradesh, West Bengal and Orissa. Goa had the lowest record of stranding. A&N had 15 records while from Lakshadweep, only 8 records have been reported.

# Diversity modelling in a wetland

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Vembanad lake, a brackish water environment in Kerala was designated UN heritage site and Ramsar site considering the ecological significance and its indispensable ecosystem services in 2002. The study encompassed the assessment of relationship between physico-chemical variables and diversity and identification of stable season for the system in a diversity perspective. The geographical location of the lake ranged between latitude 9.512 N- 10.186 N and longitude 76.163E - 76.429 E. The fish samples were collected from various landing centres in Vembanad lake. CIFRI survey during 2017-18 recorded 38 species belonging to 38 genera, 23 families and 9 orders in total. Season wise ichthyo-diversity assessment indicated that the 32 species were recorded from the lake during pre-monsoon belonging to 30 genera, 23 families and 9 orders. Canonical correspondence analysis (CCA) and K-dominance models in PRIMER 6.0 were performed for the study. CCA indicated that first and second axis represented 54.69% and 45.31% of the total variations among the variables with eigen values 0.4759 and 0.3943 respectively. The analysis indicated the eurytopic nature of the species during post monsoon. The dominance plot indicated that the system was stable during pre-monsoon with less than 20% diversity compared to other seasons. Diversity assessment using indices also substantiated increase in diversity during pre-monsoon. Shannon diversity was found maximum during pre-monsoon (2.78) compared to post monsoon (1.83) and monsoon (1.67). The study provided a quick reference on diversity of Vembanad lake with reference to water quality variables and suggested management measures in tune with the diversity aspect of the lake.

Theme 4

# Climate change and meeting SDG-14 goals

mbai-mecos 3

# Role of Blue Carbon Habitats in Mitigating and Adapting to Climate Change

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The climate change is negatively impacting the global ocean. It includes warming and acidification of seawater, shifts in species abundance, coral bleaching, sea level rise, coastal inundation, coastal erosion, harmful algal blooms, hypoxic conditions, loss of marine mega fauna and fishery fluctuations and/or declines. The coastal vegetated ecosystems such as tidal marshes, mangrove forests, and seagrass meadows play a key role in mitigating and adapting to climate change.

These coastal habitats dissipate waves and currents and trap particles, thereby promoting the sedimentation and accretion of sediments. These ecosystems act as a natural protection against sea level rise (SLR), providing, if properly conserved or restored, an important element under- pinning adaptation to SLR (Duarte *et al*., 2013). Soil accretion rates (SARs) in healthy coastal vegetated ecosystems are comparable to or exceed SLR, thereby countering marine transgression (Sasmito *et al*., 2016). Globally, SARs average (±SE) 0.2 ± 0.04 cm/year in seagrass meadows, 0.51 ± 0.03 cm/year in tidal marshes and 0.3 ± 0.4 cm/year for mangrove forests (Kirwan *et al*., 2016; Duarte *et al*., 2013). SAR differences between locations are large, depending on factors such as geomorphological settings, sedimentary riverine inputs, and hydrodynamic energy.

These coastal habitats also sequester and store carbon and are collectively called *Blue Carbon Habitats* (BCH). Mangroves, seagrasses and salt marshes are incredibly efficient at storing carbon and they can absorb and store as much as 10 times as much carbon as terrestrial ecosystems. Significant efforts have been devoted during the last decade to understand the role of coastal vegetated ecosystems as carbon sinks through burial of organic carbon, and thus their role in climate change mitigation through $CO_2$ sequestration (i.e., the blue carbon ecosystems concept; Duarte *et al*., 2013). Recently, Mazarrasa *et al*. (2015) estimated that the inorganic carbon burial rate in seagrass beds may reach 22 to 75 Tg Cinorg/year, mostly occurring in the intertropical areas (1.5% to 5% of the biogenic carbonate production of the global coastal ocean). These are regions of intense biomineralization by corals and algae, and in desert and semiarid climate regions, where terrigenous inputs are limited by the lack of surface runoffs, weathering of reefs and bio herms could be the principal source of sediment to the near shore area. This suggests that in those regions, seabed elevation would be mainly supported by the accretion of carbonates.

In addition to mitigating the impacts of climate change by sequestering and storing carbon, the BCH habitats traps large quantities of contaminants including microplastics. Because of their capacity to capture, produce and retain sediments, BCH represent important sinks for contaminants such as trace elements, hydrocarbons and microplastics.

## Case study from the Saudi waters of Arabian Gulf and Red Sea

We studied the role of BCH in accumulation of carbonates, organic carbon sequestration and storage, accumulation of contaminants (trace metals and hydrocarbons) and the burial of microplastics using sediment core samples collected from BCH along the coastline of the Kingdom of Saudi Arabia in the central Red Sea (2015) and the Arabian Gulf (See: Cusak *et al.*, 2018; Saderne *et al*, 2018; Asok *et al.*, 2019; Lotfi *et al.*, 2019; Martin *et al.*, 2019).

A total of 52 cores (1 - 4 m deep) were sampled along 80-km coastline of the Kingdom of Saudi Arabia in the central Red Sea (2015) and the Arabian Gulf (2016) and it includes 29 in mangroves forests and 23 in seagrass meadows (Figure 1). The soil cores were segmented into 1-cm-thick slices and short-term (last decades to century) and long-term (millennia) soil chronologies were established using $^{210}Pb$ and $^{14}C$ analyses, respectively. Calcium carbonate ($CaCO_3$) contents and depth profiles were determined in every fourth to fifth centimeter from surface to 20-cm depth.

C stocks per unit area were calculated by stocks in each segment interval (g C $cm^{-2}$) down to 20 cm for the sediment cores. Average short-term C burial rates were estimated by multiplying sediment accumulation rates (g $cm^{-2}$ $yr^{-1}$) by the fraction of C accumulated to 100 year depth determined by $^{210}$ Pb dating. Concentrations of trace metals and hydrocarbons were estimated

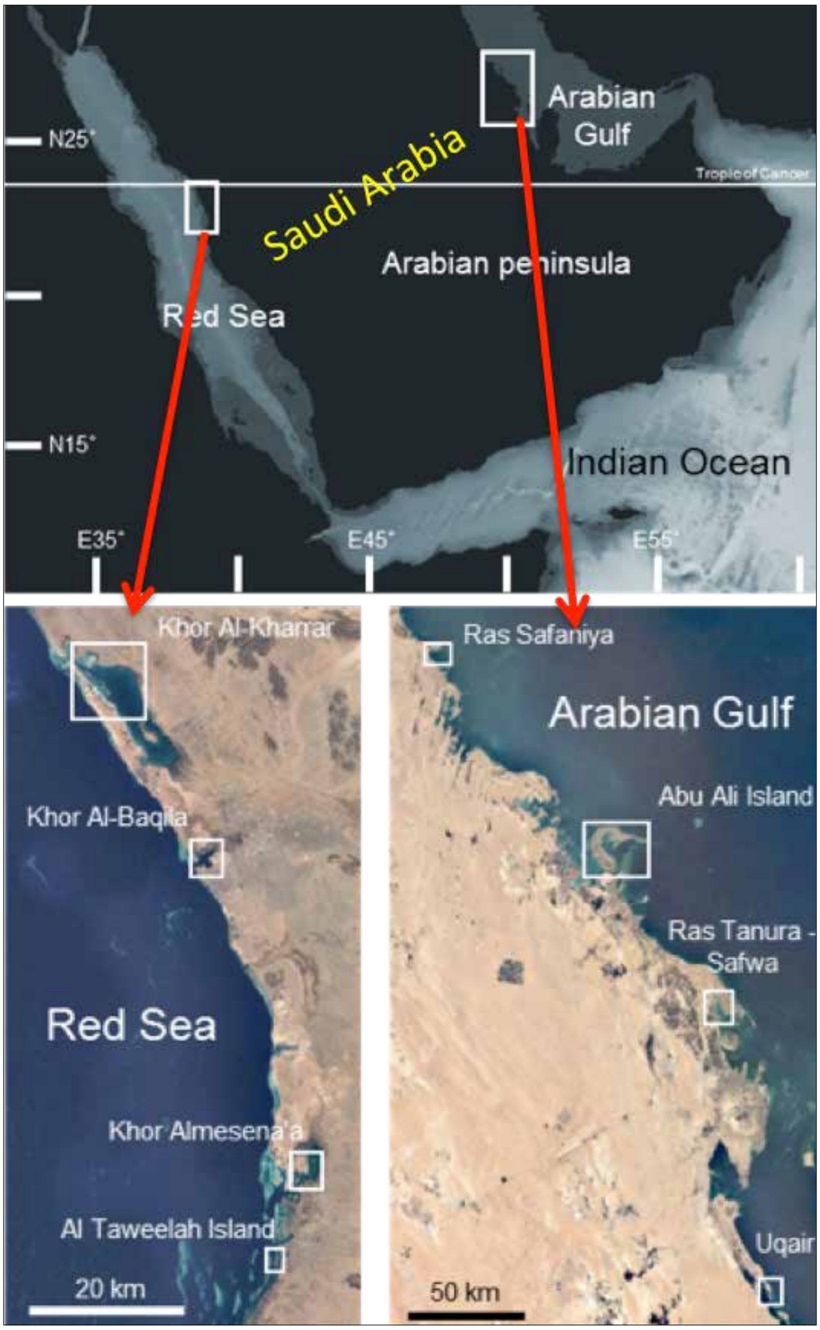


Fig. 1. Map showing the coastal vegetated ecosystems sampled in the central Red Sea and Arabian Gulf.

sediment samples collected from different depths belonging to different periods. The top slice and other 4 to 12 slices per core were processed for microplastic extraction and processed a total of 127 samples dated from 1832 to 2015 by following standard procedure.

## Study findings and conclusions:

Our study showed that mangrove and seagrass (Red Sea only) seabed elevation rates are equivalent to sea level rise rates of the twentieth century (Saderne *et al*, 2018). This is possible because of accumulation of carbonate sediment coming from coral reefs weathering, replacing terrestrial inputs in the tropical arid area. Our study strengthens the relevance of wetlands to human societies in the mitigation of climate change, and we emphasize the need to protect and restore them.

Our results also showed that mangroves, seagrass and saltmarshes along the western coast of the Arabian Gulf are acting as active $CO_2$ sinks, burying substantial amounts of carbon in their sediments on an annual basis, and contain moderate stocks of sequestered carbon, comparable per unit area among habitats, but largest at the regional scale in seagrass meadows (Cusak *et al*., 2018). The destruction or disturbance of these habitats could result in the remineralisation of a fraction of the stored carbon, giving rise to significant $CO_2$ emissions, while also making the ecosystems incapable of acting as carbon sinks in the future. Restoration of these habitats, particularly mangroves that have suffered the greatest losses, offer opportunities to contribute to mitigate climate change through $CO_2$ sequestration, while also helping to protect the shore- lines from sea level rise.

Our results demonstrated that the coastal vegetated habitats in the Arabian Gulf act as intense sinks of trace metals, hydrocarbons and microplastics, thereby extending the role of these habitats as sinks for pollutants (Asok *et al*., 2019; Lotfi *et al*., 2019; Martin *et al*., 2019). The burial rates of petroleum hydrocarbons has increased over the past decades reflecting the history of industrial petroleum exploitation in the region, with the burial across habitats reflecting past sea levels at the time of input of petroleum. We estimated stocks of 90 and 260 tons of plastic in seagrass and mangrove sediments across the Red Sea and Arabian Gulf, respectively. Our study also demonstrated that sediments in vegetated coastal habitats provide long-term archives of contaminants and burial rates reflecting human activities in the region.

One of the main concerns with BCH is the rate of loss of these important marine ecosystems is much higher than any other ecosystem on the planet, even compared to rainforests. Current estimates suggest a loss of 2-7% per year, which is not only lost carbon sequestration, but also lost habitat that is important for managing climate, coastal protection, and health. Restoration of these habitats, particularly mangroves that have suffered the greatest losses, offer opportunities to contribute to mitigate climate change through CO sequestration, while also helping to protect the shorelines from sea level rise.

# Meeting SDG 14 goals in 'Anthropocene': The Indian challenge

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In the new geological epoch of Anthropocene and climate change, meeting SDGs, including SDG 14 ("Conserve and sustainably use the oceans, seas and marine resources for sustainable development") in a serious, systematic and timely manner, is no longer a matter of choice before states, economies and societies but dire necessity. With growing ascendance of the highly seductive concept of 'Blue Economy', inviting policy attention across the globe -that too against the unsettling backdrop of uneven development, structural inequalities in power relations, excessive extraction of resources by and glaring reality of ecological crisis caused by 'carboniferous capitalism'—India, home to 13% of the global population, needs to pursue SDG 14 both with a sense of urgency and some caution.

*Sustainable Development Goals India Index*, released by the *NITI Aayog* in 2018, acknowledges that 40% of world ocean is already heavily affected due to depleted fisheries, ocean acidification and loss of coastal habitats. Highlighting the importance of 'Blue Economy' in the Indian context, it lists out Government of India initiatives (e.g. National Plan for Conservation of Aquatic Eco-systems, project SAGARMALA, Mangrove Forest Management, Marine Protected Areas), and national/sub-national legislations for the management and protection of the coastal and marine environment. Whereas the *Voluntary National Review Report on the Implementation of Sustainable Development Goals* presented by India to the High-Level Political Forum on Sustainable Development of the United Nations in July 2017, rightly underlines the importance of "integrating the SDGs into its on-going national and sub-national policies and programmes", and building partnerships both regionally and globally.

The twin mandate of the *NITI Aayog* is to "oversee the implementation of the SDGs in the country" and also to promote "Competitive and Cooperative Federalism among States and UTs", while, "aligning the SDGs with the Prime Minister's clarion call of *Sabka Saath, Sabka Vikas,* which embodies the five Ps of the global SDG movement - *people*, *planet*, *prosperity*, *partnership* and *peace*." It is significant to note that progress with regard to SDGs 12, 13 & 14 could not be measured due to the non-availability of relevant State/UT level data.

Taking the Bay of Bengal as a case in point, and deploying critical social science lenses, an interdisciplinary examination of SDG 14, its seven targets and three provisions on means of implementation gives credence to the need for relocating the Indian challenge of securing sustainable futures on the intersections of SDGs-Anthropocene-Blue Economy/Blue Revolution. Doing so reveals not only the mismatch between ecological boundaries and political/administrative boundaries but also an extraordinary complexity and differentiation in terms of *stocks* (e.g. ecological-carbon footprints), *scales* (i.e. local, sub-national, national, sub-regional, regional and global) and *stakes/stakeholders* (communities, businesses/markets, governments, local bodies and civil society etc.). This in turn calls for an inclusive, transparent and socially just approach towards decision/policy making, skilful management of trade-offs among different sectors of the Blue Economy, and due emphasis on enhancing synergies and cooperation amongst diverse agencies and institutions. The legitimacy, authority and effectiveness of the Indian pursuit of SDG 14 and its outcome would largely depend on the extent to which it is faithful to global obligations/norms, receptive to best practices and mindful of the perceptions and priorities of local communities, especially the small scale marginalized artisanal fishers.

# Need for segregation of litter in Mangaluru

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The monitoring of beach debris began after it was understood to be a threat to the marine environment and coastal communities (U. S. Commission on Ocean Policy, 2004). Globally, many communities have lost millions of dollars from declining tourism due to beach litter and increased beach clean-up and maintenance (NRC, 1995). Knowledge about the quantity and characteristics of litter is essential to plan for its effective management. It has already been reported that in cities, the amount of litter could double in the next 20 years, which could make the work of administrators much more cumbersome. In Mangaluru the three major beaches for tourism, trade, and fishing are Thaneerbhavi, Panambur, and Chitrapur. Thaneerbhavi Beach is mainly used as a local tourist beach. Panambur Beach has a major port and facilities for traditional fisherfolk to land their boats throughout the year. Chitrapur Beach is adjacent to the residential area of the fishing community. Most of the litter collection activities on the beaches are performed informally (i.e., by volunteers); materials that are recyclable are most commonly collected. The United Nations (UN) Sustainable Development Goals and the "New Urban Agenda" (United Nations, 2014), call for improvements in litter management practices as a basic service to citizens.

Monthly litter samples were collected from three major beaches in Mangaluru from 2011-2016 and classified based on United Nations Environmental Programme/Intergovernmental Oceanographic Commission guidelines. The length and abundance by number of items ($m^{-2}$) and by weight (g $m^{-2}$) were measured after beach sampling. To understand the sources, transportation, and deposition of litter, environmental data from secondary sources were collected in addition to monthly measurements of salinity and beach width. Three seasons were identified: summer (S: February-May), south-western monsoon (SW: June-September), and north-eastern monsoon (NE: October-January). The variation in salinity in the surf zone of the beach was measured potentiometrically using a multi-parameter instrument (WTW 320i, Xylem Analytics LLC, Germany). Monthly river discharge data were obtained from the Cauvery and Southern

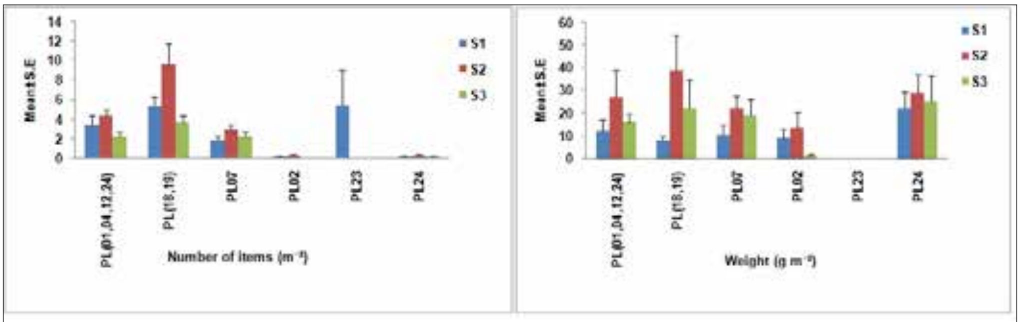


Fig. 1. Variability in plastic litter abundance by number ($m^{-2}$) and weight (g $m^{-2}$) for the three beaches, Thaneerbhavi (S1), Panambur (S2), and Chitrapur (S3), from 2011-2016. Error bars represent 95% confidence intervals.

Rivers Organization, Coimbatore. Meanwhile, data on monthly rainfall, rainy days, and wind velocity were obtained from the Department of Economics and Statistics, Government of Karnataka, and those on the population density near the beaches were obtained from the Socioeconomic Data and Applications Centre (SEDAC, 2011). Comparisons of the means, Pearson's correlation, and analysis of variance (ANOVA) were performed using the SPSS v. 16 software package. Percent changes in litter composition were calculated and graphs were prepared in Microsoft Office Excel 2007.

Fishing litter persisted at the beaches, resulting in higher abundances by number (59%) and weight (33.4%) relative to all litter in 2016. In addition to plastics, foam comprised 7.14-11.0% of total litter. Significant positive correlations were observed between the amount of plastic on the beaches and rainy days, rainfall, and river discharge. The monsoon also transported and deposited residents' plastic litter and glass on the beaches through adjacent drains and rivers. Fig. 1 depicts the variability in plastic litter abundance by number ($m^{-2}$) and weight ($g\ m^{-2}$) for the three beaches, Thaneerbhavi (S1), Panambur (S2), and Chitrapur (S3), from 2011-2016. Yearly quantities of plastic items ($p < 0.01$), plastic bags ($p < 0.001$), and plastic footwear ($p < 0.05$), on the beaches were significantly different. The total beach litter data revealed that Panambur Beach was the least changed, and thus appropriate incentive-based management options for fishermen should be adopted by policymakers in that area.

# Impact of Tropical Cyclones on the Marine Fishery landings and their Intervening Linkages with El Niño Southern Oscillation

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Tropical cyclones are one of the most destructive natural hazards. India is exposed to almost 10% of the world's total cyclones and the fishermen communities are most vulnerable to the impacts of cyclones. Storm surges, heavy rains and strong winds associated with tropical cyclones can damage the coastal ecosystem. The impacts of tropical cyclones on the monthly fishery landing of Kerala and Tamil Nadu coast from 2007-2018 were assessed for this study. During this period 7 cyclones have affected the Tamil Nadu coast. Among the seven, four were very severe cyclonic storms. Of the 12 years, the Kerala coast was hit by only one cyclone (cyclone Ockhi). For assessing the variation, fishery catch during the cyclone period was compared with the normal monthly catch (average of cyclone unaffected years catch). The result reveals that, all these cyclones had a significant impact on the marine fishery catch both on the mechanized and non-mechanized sectors. However during the month of cyclone Nilam in 2012, mechanized sector of the Nagapattinam District recorded an increased catch. El Niño Southern Oscillation (ENSO) is a coupled ocean atmospheric phenomena of the periodic fluctuation in sea surface temperature and the air pressure across the equatorial Pacific Ocean. ENSO is considered as a global phenomenon because of its ability to change the global atmospheric circulation. ENSO has a significant effect on the tropical cyclone activities. The previous studies reveals that, Bay of Bengal post-monsoon cyclone activity, including intensity, frequency, accumulated cyclone energy (ACE) and power dissipation index (PDI) showed a significant negative correlation with Nino 3.4 index. In this study 30 years (1989-2018) Arabian Sea and Bay of Bengal cyclone data including the cyclone category, wind speed and atmospheric pressure were correlated with the 6 ENSO indices [Trans-Nino index (TNI), Multi-variate ENSO index (MEI), Southern oscillation index (SOI), Niño 3.4, El Niño modoki index (EMI) and Oceanic Niño index (ONI)]. Higher sea surface temperature (SST >26.5˚C) is the primary criteria for the genesis of tropical cyclones. Thus, SST plays a considerable role on the tropical cyclone formation. Therefore SST of the Arabian Sea and Bay of Bengal were also correlated with the cyclone data. The Bay of Bengal SST is positively correlated ($r=0.18$, $p<0.05$) with cyclonic wind speed. Nonetheless, there was no correlation with atmospheric pressure. A negative correlation exist between Nino3.4 index and cyclonic wind speed ($p<0.05$) and a positive correlation is found between SOI and cyclonic wind speed ($p<0.05$). All indices showed a weak correlation with cyclonic wind speed. But not all were significant. In Arabian Sea, the Pearson's correlation analysis showed no significant correlation with ENSO and Arabian Sea cyclonic activity. The general trend in the tropical cyclone formation in the Arabian Sea and Bay of Bengal basins were also assessed. For this analysis, the Mann-kendall trend test was used. From the result, the total number of cyclones in the Arabian Sea showed a positive trend and the Bay of Bengal showed a negative trend. But this monotonic increase/decrease in the number of cyclones formed in the Arabian Sea / Bay of Bengal is not statistically significant. The Wind speed determines the destructive power of the cyclones and the influence of ENSO on the cyclonic wind speed is helpful for the seasonal cyclone predictions. So the SOI and Nino3.4 indices can be useful for the seasonal cyclonic predictions in the Northern Indian Ocean.

# Impact of extreme events on coastal dynamics and small pelagic fishery along the west coast of India

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Recent studies have reported that the Indian Ocean is warming as a result of teleconnections associated with extreme climatic events. The impact of such events on ocean dynamics and concomitant changes in Essential Climate Variables (ECVs) disrupts the reproductive potential and often imply large fluctuations in recruitment of small pelagic resources. The present study investigates the variability in ECVs along the west coast of India and plausible challenges of the small pelagic fishery during extreme events. The study also attempted to forecast the fishery using climatic projection data obtained from coupled CMIP5 climate model. Sea Surface Temperature (SST) and chlorophyll-a (Chl-a) data were acquired from Ocean Colour- Climate Change Initiative (OC-CCI) and Woods Hole Oceanographic Institute (WHOI) respectively. In addition, the sea surface wind data attained from Asia-Pacific Data-Research Centre (APDRC) were used to derive upwelling index. Fishery data of gear-wise landings and fishing effort during 1985 to 2018 were acquired from National Marine Fisheries Data Centre (NMFDC) of Central Marine Fisheries Research Institute (CMFRI). Long-term analysis of SST revealed a strong association in the western Indian Ocean with increased warming signatures in the coastal waters of south west coast of India. The occurrence of extreme events such as Indian Ocean Dipole (IOD) and El Niño Southern Oscillation (ENSO) were noticed during the study period and observed significant impact on ECVs in the study region. The analysis of monthly SST anomaly exhibited significant relationship with IOD and ENSO events during the study period. The future climate projections were carried out for SST, Chl-a, and rainfall during 2030, 2050, and 2080 under different RCP scenarios namely RCP4.5, RCP6 and RCP8.5. Time-series analyses of the future projections were used to explain the possible future implications on small pelagic fishery. The study attempts to explore the variability in coastal dynamics and major small pelagic fishery of an upwelling-dominated coastal region under extreme climatic events.

# Resilience capacity of a Lakshadweep Atoll

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Coral reefs are the rainforests of the ocean, which sustain a wide variety of marine organisms. If the value of goods and services provided by coral reefs is considered, it will be of a huge amount costing 352,249 US dollars per annum. The past decade was not so promising for coral reefs and they have been going through the most difficult time in their life history. Numerous reports on the global decline in coral reef habitats in the form of decreased coral cover, change in the structure of the coral community, alteration in the ecosystem system services or transition to non-reef ecosystems. Resilience based management is considered as one of the solutions to overcome the current situation. Chetlat (Lat 11.689°, Long 72.707°) is one of the northernmost inhabited atolls in the Lakshadweep Sea, which is one among the five islands in the Amindivi group of islands. Chetlat is part of the world's largest true atoll system known as Lakshadweep- Chagos Archipelago (LCA). Corals in this region are highly susceptible to bleaching due to rising sea surface temperatures, especially during El Nino years. The current study aims to delineate the resilience potential of reef segments of the Chetlat atoll focusing on the lagoon side of the island. In this study, we selected 12 different stations throughout the lagoon and collected data on various indicators to estimate the resilience potential of different stations. The selected indicators are coral diversity, coral cover, coral recruitment, resistant coral species, macroalgal cover, average herbivore biomass and disease prevalence. Video transects and photos were also used for detailed observation. Total coral cover in the lagoon is estimated to be a total of 42.6 hectors were 28.2 hectors in the north side of the lagoon is dominated by *Helipora coerulea* and these stations are found to be less diverse than the remaining stations. Coral diversity is a major indicator of resilience so the blue coral dominated reef patches are found to be less resilient than other reef patches. This should due to the competitive success of *H. coerulea* over other scleractinian species. The primary drivers of the coral resilience of Chetlat Island are delineated. Targets for management actions are formulated for each station based on the assessment results.

# Are our reefs changing? Evidence of gradual phase shifts occurring in the Atolls of Lakshadweep

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Climate change is curtailing the sustainability of coral reefs worldwide. Lakshadweep chain of atolls is the largest atoll system in the world and is highly vulnerable. The change in climate is stressors to unprecedented levels. Under such traumatic conditions, the corals are expelling the algae with whom they share a symbiotic relationship and thus the corals bleach. The mass bleaching of corals can result in their heavy loss if they are not resilient to this. In this study, selected atolls of Lakshadweep were surveyed extensively using the quadrat method. The changes in the status of the reefs were studied and the data about the coverage of benthic community structures were recorded at regular intervals. The results show that the extent of live corals is gradually decreasing which is partly accelerated due to overgrowth of algae and anemones over the dead and even live corals. Such results point to the fact that prolonged stress on corals leads to the death of the coral polyps of the reefs and these instances are well utilized by the opportunistic organisms which lead to the dominance of unwanted organisms on the benthic substrate. Otherwise, a phenomenon of change in the functional state or a phase shift might be happening in these coral reefs. A better understanding and assessment of phase shift, its mechanisms and drivers will play a key role in the conservation of coral reefs as phase shifts indicate an urgent need for modified management strategies to prevent the reefs from further deterioration.

# A preliminary assessment of the blue carbon storage potential of fragmented mangrove sediments of Vembanad Lake, India

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Coastal mangrove ecosystems are very important in view of climate change mitigation potential as they can capture and store huge quantities of carbon in the system for a very long period of time. They are more efficient in sequestering and storing carbon than terrestrial ecosystems like forests and it is estimated that on per area basis, coastal ecosystems store carbon in the sediments at rates ten times greater than that of forests. Mangrove ecosystems accrue more sequestered carbon in their sediment and it has been reported that 50% of the carbon storage in marine sediment is contributed by a meagre 0.5% of the ocean area occupied by mangroves. More importantly, the sediment carbon pools of mangroves amount to 75% of their total carbon sequestration, which emphasise the importance of assessing, monitoring, managing and inventorying of the blue carbon stocks of our mangrove ecosystem. An accurate inventory of the same can help us formulate appropriate policies towards climate change mitigation and blue carbon trade.

Mangrove habitats are forests found in tidally inundated areas, observed as dense or fragmented vegetative stand. The mangroves in Kerala cover only 2502 ha and are patchy and fragmented. Vembanad Lake, the second largest brackish water lake in India, encircled by mangroves, mudflats, swamps and marshes is one among the most dynamic, life-supporting coastal wetlands of Kerala. In this study, we estimated the blue carbon stocks of Vembanad Lake mangrove patches of Ernakulam District at selected locations.

The high resolution imageries available in the public domain were used to identify the location and to derive the extent of selected mangrove patches in the area. These operations were done in a GIS environment. Stock assessment of blue carbon pool of mangrove sediment was done using the standard protocols for assessing blue carbon stocks in coastal ecosystems on per *ha* basis and it was multiplied with the estimated area to derive the blue carbon stock of the particular mangrove patch.

The area of the studied patches varied from 0.01 ha to 59.86 ha with a mean area of 3.2 ha and the total extent was 80.51 ha. The sediment blue carbon storage varied from 17.38 MgC $ha^{-1}$ to 139.96 MgC $ha^{-1}$ with an average value of 49.54 MgC $ha^{-1}$. Depending on the extent of the mangrove patches and the carbon storage density, the blue carbon stock varied from 0.17 MgC to 4010.62 MgC for different patches and the total blue carbon stock in the studied area was 4956.82 MgC.

It was found that the mean blue carbon storage density in the mangrove sediment of the study area is to the tune of 49.54 MgC $ha^{-1}$ which is far below the mean global soil organic carbon stock in the mangrove ecosystem (386 Mg $ha^{-1}$). This finding offers the opportunity to sequester more carbon in our coastal mangrove ecosystems through proper management there by contributing to climate change mitigation efforts.

# Recent developments in building the resilience of Hexacorals in a changing climate

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Coral reefs are facing severe threats including mass coral mortality due to increasing sea surface temperature caused by global warming. Various published literature have already predicted that the reefs might disappear within 20 to 50 years which concludes corals will not be able to adapt to the accelerating rate of climate change. This study provides a brief review on recent development processes practised for maintaining resilience on Hexacorals that provide strong, diverse coral settlement and growth in a changing climatic condition. The resilience of Hexacorals is gradually declining as they fail to recover after the recurrent disturbance and from the pulse of coral mortality. Some coral species such as *Acropora* and *Pocillopora* are more susceptible to thermal stress; they mature early, grow rapidly and suffer whole colony mortality. Recent studies show that thermal acclimatization of corals is causally related to the zooxanthellae symbionts mainly the *Symbiodinium* clades. Identification of Symbiodinium upto species level is difficul even using the molecular methods. Hence commonly adopted method in the ecological level studies is to describe different clades of this symbiont. Till date clades A-H have been described from different members of coelenterates. *Symbiodinium* species belonging to clade D shows high tolerance against the thermal stress which gives new insights into the ecological advantage of corals with such clades. There are attempts towards alteration of the zooxanthellate composition of different coelenterates to increase their resistance towards specific climatic variables. Focusing on developments with resilience-based science could guide improvements in coral reef management against future climatic challenges. The major features that a healthy and resilient coral reef needs are: strong coral recruitments, low human impacts and healthy herbivore population. Strong recruitments are measured by both the number and the cover of small coral colonies established in the area since the prior disturbance. Coral restoration using larval propagation process was practised in many countries such as Australia and the Philippines, coral spawn are captured from healthy corals and then reared for development. These larval recruits are protected under the marine protected area for strong and rapid recovery of damaged reef. Building coral reef resilience through spatial herbivore management is also another recent resilience-building tool used to maintain resilience in areas with frequent and severe bleaching events.

# Impact of global warming in the virulent features of zoonotic pathogens from aquatic environment

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Global climate change is escalating average worldwide temperature which is predicted to increase by 1.8-4.0 °C during 21st century as per the Intergovernmental Panel on Climate Change (IPCC). Concurrently, an augmented incidences and/or severity of infectious diseases have been observed in humans and marine ecosystems. This correlation between temperature and infectious diseases has become a growing concern to both human, veterinary and aquatic medicine. Understanding the ways in which the virulence factors of pathogens are regulated by temperature can help to design and implement effective and suitable strategies to mitigate various infectious diseases. Accordingly, the present study was designed to explore the ways in which the change in environmental temperature will affect the virulence of five aquatic zoonotic pathogens namely, *Vibrio vulnificus*, *V. parahemolyticus*, *Aeromonas veronii*, *Shewanella putrefaciens* and *Streptococcus agalactiae*. For this, the representative strains of pathogens were procured from Aquatic Bacterial Culture Collection Centre, Marine Biotechnology Division, ICAR-CMFRI, Kochi. After the species confirmation, the isolates were screened for the presence of seven putative virulence traits namely protease, lipase, gelatinase, lecithinase, haemolysis and siderophore production as well as serum survival in naïve main targeted host. All these tests were then conducted in different temperatures (21, 24, 28, 31, and 34°C) symbolizing the present and past-global surface water temperature. While evaluating the effects of temperature on growth rate, it was found that it is not the major factor influenced by the change in environmental temperature. Conversely, all the evaluated virulent features except lecithinase (not in *V. parahemolyticus*) and haemolysis, were found to be positively or negatively influenced by the change in temperature. In case of *V. vulnificus* and *S. agalactiae*, all the four virulent features were increased with increase in ambient temperature. For *A. veronii*, all the three virulent characters were elevated at higher temperature while lipase production was unaffected. Conversely, *S. putrefaciens* and *V. parahemolytics* exhibited higher lipase and gelatinase production respectively at higher temperature while maintaining a stable activity in other virulent mechanisms. Subsequently, *in-vitro* survival tests of the two pathogens (*V. vulnificus* and *S. agalactiae*) in which maximum virulent features were affected by the change in temperature, was carried out to check their multiplication within the serum of naïve main targeted host (Nile tilapia-*Oreochromis niloticus*). Bacterial survival ratio was higher in serum than control at the completion of incubation period in all temperatures, showing that both pathogens have the ability to survive and effectively multiply in serum of their host. One-way ANOVA with Tukey's post-hoc analysis showed statistically significant difference in serum survival ratio between three different temperatures as a whole, and survival was significantly higher at 31°C than at 25°C and 28°C ($p<0.05$). This result indicated that there is an increased chance of infective capacity of *both strains* at higher temperature. Overall, our results showed that pathogens showed a marked difference in their virulent features in response to difference in ambient temperature and many virulent factors are affected by the rise in temperature. The present study sheds some thought provoking insights on the ways through which the change in environmental temperature can affect the virulence of five selected zoonotic pathogens. Simultaneously, increased virulence of pathogens and enhanced survival within the targeted host.

# Removal of toxic wastes from the effluents of fish processing industries through bioremediation

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The waste water discharges from fishing harbour, fish market and the fish processing plants are the major sources of organic load in the natural water bodies leading to eutrophication and environmental pollution. Waste water samples (effluent) collected from Chambakara, Thevara fish market and seafood processing plant at Kochi, Kerala were subjected to the process of bioremediation by aquatic plants serves as an effective method to improve the physicochemical parameters of effluent water. Nitrogenous compounds such as ammonia, nitrate and nitrite found to be higher in effluent water. Similarly the phosphate and silicate content was also high in industry sample. Upon treatment there was an increase in DO and reduction in nitrogenous compound but in case of ammonia the reduction was from 2-10%. The volatilization of the ammonia was observed in indoor experiment. Ammonia, nitrate and nitrite contents in the industrial effluent were found to be higher than the market sample with a very high value of (3.95mg/l). The Ammonical nitrogen showed comparatively less absorption (5-15%) with highest decline in T with *E. crassiceps*. The overall decline of nitrite ranged from 24 to 47% and nitrate by 27-44 % with higher efficiency by T *E. crassiceps* followed by *P. straitoes*. There was a gradual decline of phosphate ranged between 50-55% after 10 DAT. Maximum changes was observed in silicate content showing decline between 44-91% with T showed highest decline of silicate 91% followed by 90% in T 88% in T and 44% in control. *Eichhornia crassipes* is effective in improving the quality of effluents from fish processing industry and the market samples whereas *Pistia stratiotes* could able to reduce the phosphate contamination better. The industrial effluent sample was very rich in protein and lipid. Protein content of 1.718g/l and lipid of 2.388 g/l from the effluent of the fish processing industry is generally discarded back into the waste stream, resulting in the loss of valuable components, especially soluble proteins with good functional and nutritional properties. Recovering proteins and lipid would reduce the negative environmental impact and generate potential profits.

# Phyco-remediation capabilities of three different micro algae on domestic sewage water

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Phyco-remediation is the process of employing algae for removing excess nutrient load from wastewater and subsequently diminishes the pollution load. It is an alternative technology of treating sewage wastewater compared to conventional treatment process in economical and sustainable way. In the present investigation we had made an effort to phyco-remediate the domestic sewage wastewater with three different microalgae viz. *Nannochloropsis* sp, *Chaetoceros* sp, *Isochrysis* sp. Domestic sewage water was collected from Lawson's bay area. It was centrifuged at 3000 rpm for 45 minutes to get a supernatant. The supernatant was then used along with the Conway media for algae culture. Light intensity was provided at 2500 lux for 24 hrs. Continuous aeration was also provided. Parameters such as TAN, nitrate, nitrite and phosphate were analyzed at the beginning and end of the experiment. Results of this experiment showed that all these algae's were very effective in reduction of TAN, nitrate, nitrite and phosphate in sewage wastewater. Further it has also been observed that *Nannochloropsis* sp. was having the best phyco-remediation potential as well as growth followed by *Isochrysis* sp. and *Chaetoceros* sp. among all the three microalgae studied.

# Studies on the bioaccumulation of microplastics in bivalves of urban beaches of Mumbai

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Plastic is a highly versatile, multi-utility substance which is used throughout the world and it became unavoidable in day to day life. These plastics are susceptible to disintegration into smaller particles and those particles of size less than 5 mm are termed as micro-plastics (MPs). These are ubiquitous in marine environment. Many aquatic organisms, including zooplankton, invertebrates, fish, bivalves, incidentally consume MPs from sediment or the water column, mistaking them as food and then biomagnified to animals at higher tropic levels which in turn feed on them. Among these organisms bivalves are excellent filter feeders and approximately filter 24 liters per day and accumulate these micro-plastics in their gut and tissues and thus can be used as bio indicators for plastic pollution status of that region. Microplatics related observations, highlighting its implications to bivalves, are available globally, but in Indian context only very few studies have been conducted so far. In present investigation, most polluted urban beaches like Juhu, Bandra and Navi Mumbai industrial areas of Mumbai city with a population of 1.3 crores were selected and bivalve samples were collected. Chemical digestion and visual identification of bivalve tissues under microscope reveals lot of micro-plastic fibers and fragments of varying colors (red, black, transparent) and sizes (2-300 microns) indicating the extent of anthropogenic pollution in Mumbai beaches. The presence of microplastics in seafood pose a threat to food safety. This work can help us to know the plastic pollution status of Mumbai and can guide the policymakers in framing rules for sustainable plastic usage.

# The occurrence of microplastic in the coastal waters and selected commercially important fishes of Palk Bay and Gulf of Mannar along southeast coast of India

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The study investigated the presence of microplastic in surface water and fishes of Palk Bay and the Gulf of Mannar in Southeast coast of India during June, 2019. The study area included four stations such as Agnitheertham (N-09⁰ 18' 14.2" E- 079⁰ 20' 2.4") and North Pampan (N 09⁰ 16' 15.0" E- 079⁰ 09'26.7") in Palk Bay and Vedhalai (N-09⁰ 15' 40.6 E- 079⁰ 06' 44.0") and Kilakkarai (N-09 17' 15.8", E-079⁰ 09' 26.7") in the Gulf of Mannar. The average atmospheric temperature (30.12 ±1.03 °C), sea surface temperature (30.87 ± 0.85 °C), pH (7.7 ± 0.12) and salinity (36.25 ± 0.95ppt) were observed. The microplastics in surface waters (5 to 7m depth) were collected by horizontal hauling using net of 100µm size at a speed of 1knot for 10minutes. The abundance of microplastic in the surface water and fishes were examined. The microplastic concentration was comparatively highest in Palk Bay in North Pampan (0.66 no./m $^3$) and Agnitheertham (0.135 no. /m $^3$). The major type of microplastic was constituted by blue fragments which ranged from 0.46 to 4.67mm in size. Plastic waste was found to be accumulated on the beaches (Fig.1) and entangled in coral beds of Palk Bay (Fig.2).

Further, the occurrence of microplastic was analyzed in 95 individuals of fishes belonging to five different species including *Pelates quadrilineatus*, *Terapon puta*, and *Hyporhamphus quoyi* from Palk Bay and

Fig.1. Plastic waste accumulated in beaches of North Pampan

Fig.2. Plastics entangled in coral beds of Palk Bay

*Sardinella albella* and *Leiognathus equulus* caught from the Gulf of Mannar. The presence of about 4.21% of microplastics was examined from gut of two different fish species with maximum in *Pelates quadrilineatus* (3.15%) and minimum in *Sardinella albella* (1.05%). The type of microplastics obtained from fish gut included filament (1.24 mm), fragment (0.881 mm), fragment (1.63 mm) and filament (0.6 mm) (Fig.3). The study indicated the occurrence of microplastic in coastal ecosystem of Palk Bay and Gulf of Mannar, the regions which are highly exposed to fishing, tourism and pilgrims activities throughout the year. Hence, its negative impact on the ecologically important ecosystem and its biota was evident.

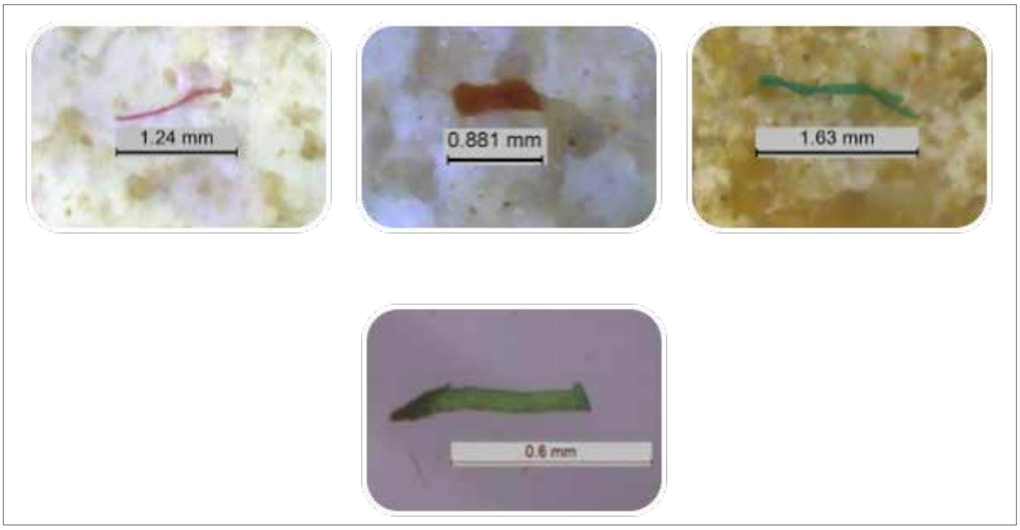


Fig. 3. Microplastics obtained from the gut of *Pelates quadrilineatus* (top ) and *Sardinella albella* (bottom)

# Oil and grease monitoring in clam beds of Netravathi estuary

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In open waters where, bivalve fishing is carried out, the anthropogenic activities and pollutants including oil & grease will affect the survival of the bivalves. Oil residue from workshops, automobiles, refineries, oil terminals, depots, merchant ships, fishmeal plants and tankers get discharged into the rivers and contaminate the estuaries which eventually reach the coastal environment. Oil pollution may directly or indirectly cause impact to the marine ecosystem such as coastal wetland, mangroves and also human health as the pollutant enters the food chain.

Natural clam beds in Netravathi Estuary are being monitored for bivalve biomass and sediment characteristics regularly. There are 13 fish meal plants in operation during the pre-monsoon season and post monsoon seasons with a production of 31,950 t /year. Considering the proximity of the clam beds to the fishmeal plants located near the bar-mouth the extent of oil & grease in the waters were studied from the bar-mouth, to upstream stations located at Ullala (STN1), Ullala Hoige (STN2), Permannur (STN3), Jeppinamogaru (STN4) and Bajal (STN5).

| | | |
|---|---|---|
| Barmouth | - | N 12°50.096 E 74°50.280 |
| STN1 | - | N 12°50.001 E 74°50.798 |
| STN2 | - | N 12°50.082 E 74°51.192 |
| STN3 | - | N 12°50.378 E 74°52.271 towards bar mouth. |
| STN4 | - | N 12°50.777 E 74°52.463 |
| STN5 | - | N 12°50.745 E 74°52.679 is the upper stretch of the Netravati river, about 300 m away from bar mouth |

Monthly water samples were collected during March 2016 to January 2019 and analysed according to pre-monsoon (PRM) (February-May), monsoon (MON) (June-September) and post-monsoon (POM) (October-January) seasons. Oil & grease in the water samples were quantified gravimetrically.

In pre-monsoon period, oil & grease ranged between <0.001 mg/L and 0.176 mg/L with the lowest in Jeppinamogaru station and highest in Ullala Hoige. In monsoon period the range was between 0.0013 mg/L to 0.007 mg/L with the lowest in stations near Ullala Hoige and highest in bar-mouth. In post-monsoon period the level was between 0.002 mg/L and 0.2228 mg/L with the lowest in Jeppinamogaru and Bajal stations and highest in Ullala station. These levels were below the maximum permissible limit of oil & grease in water body of 10 mg/L (Environment Protection Act 2002). During 2016, a Division Bench of the National Green Tribunal, Southern Zone, had imposed fine on the 13 fish meal units operating in Ullala after finding them guilty of polluting estuarine waters by discharging untreated effluents and ordered the closure of one fish meal unit that had been operating illegally in violation of the Coastal Regulatory Zone notification of 1991. Consequently, the oil & grease levels in the water reduced over the next 2 years. The level that was ranging from 0.0023 mg/L to 0.2228 mg/L in 2016 has come down to <0.001 mg/L to 0.0093 mg/L since 2017. The healthier water conditions were also reflected in the clam spat settlement in the Netravathi Estuary emphasizing the need for routine monitoring of sentinel bivalves for ecosystem sustainability

# Carbon sequestration potential of mangrove ecosystem in Muzhappilangad Bay of Kerala, southwest coast of India

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Mangroves are keystone ecosystems and assume significance as an alternative store of sequestered atmospheric carbon. The study was aimed to assess the blue carbon potential of a mangrove ecosystem in Muzhappilangad Bay of Kerala, south-west coast of India. Field transect surveys with 10 x 10m$^2$ quadrats were employed to record the mangrove species diversity, their biomass and carbon stock. The estimation of biomass and carbon stock were done in three carbon pools *viz*., i) above-ground biomass, ii) below-ground biomass (root) and iii) sediment. The spatial location of each sampling site (quadrat) was marked using a GPS. All the mangrove trees of each quadrat were measured for their tree girth. The estimated overall mean above-ground and below-ground (root) biomass was 260.69 and 102.84 t ha$^{-1}$ respectively. The estimates of mean combined C-stocks in the mangrove biomass and sediment of the study area showed that the mangroves stored 210.45 t C ha$^{-1}$ (above-ground 130.34 t C ha$^{-1}$, root 51.42 t C ha$^{-1}$ and sediment 28.68 C ha$^{-1}$), which is equivalent to 772.35 t CO ha$^{-1}$ (above-ground 478.36 t CO ha$^{-1}$, root 188.71 t CO ha$^{-1}$ and sediment 105.27 t CO ha$^{-1}$) (Fig. 1). Of the three carbon pools, the above-ground C-stock was the highest (66.47%), followed by the carbon stock of root biomass (26.22%) and the sediment carbon stock (7.31%) (Fig. 2). Table 1 provides the summary of above and below-ground (root) biomass and carbon. The study underscores the importance of these intertidal forests for climate change mitigation and stresses the importance of protecting the mangroves.

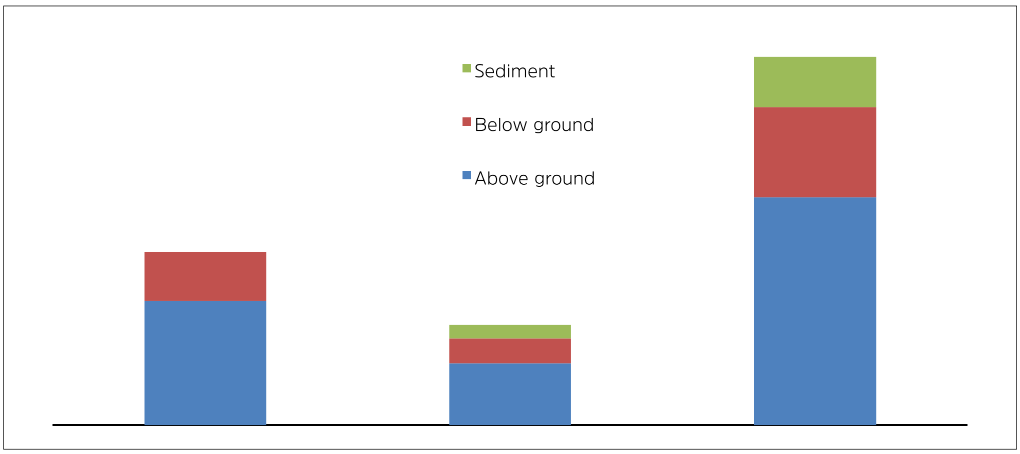


Fig. 1. Biomass, C- Stocks and Carbon-di-oxide equivalent of mangroves in the study area

of the study area

| Stations/ Quadrats | Above-ground biomass (t ha$^{-1}$) | Above-ground carbon stock (t C ha$^{-1}$) | Below-ground biomass (t ha$^{-1}$) | Below-ground carbon stock (t C ha$^{-1}$) | Total biomass (t ha$^{-1}$) | Total carbon stock (t C ha$^{-1}$) |
|---|---|---|---|---|---|---|
| 1 | 222.42 | 111.21 | 87.80 | 43.90 | 310.22 | 155.11 |
| 2 | 500.80 | 250.40 | 190.35 | 95.17 | 691.15 | 345.57 |
| 3 | 497.40 | 248.70 | 182.93 | 91.47 | 680.33 | 340.17 |
| 4 | 219.96 | 109.98 | 91.86 | 45.93 | 311.82 | 155.91 |
| 5 | 253.78 | 126.89 | 102.81 | 51.40 | 356.59 | 178.29 |
| 6 | 235.87 | 117.94 | 94.52 | 47.26 | 330.40 | 165.20 |
| 7 | 262.13 | 131.07 | 106.01 | 53.00 | 368.14 | 184.07 |
| 8 | 118.34 | 59.17 | 56.67 | 28.33 | 175.01 | 87.51 |
| 9 | 151.90 | 75.95 | 68.31 | 34.16 | 220.21 | 110.10 |
| 10 | 453.13 | 226.56 | 166.73 | 83.36 | 619.85 | 309.93 |
| 11 | 107.81 | 53.91 | 46.64 | 23.32 | 154.45 | 77.23 |
| 12 | 347.39 | 173.69 | 133.26 | 66.63 | 480.65 | 240.33 |
| 13 | 18.00 | 9.00 | 9.04 | 4.52 | 27.05 | 13.52 |
| Total | 3388.94 | 1694.47 | 1336.93 | 668.47 | 4725.87 | 2362.94 |
| Overall Mean | 260.69 | 130.34 | 102.84 | 51.42 | 363.53 | 181.76 |
| S.D | 151.76 | 75.88 | 53.84 | 26.92 | 205.51 | 102.76 |

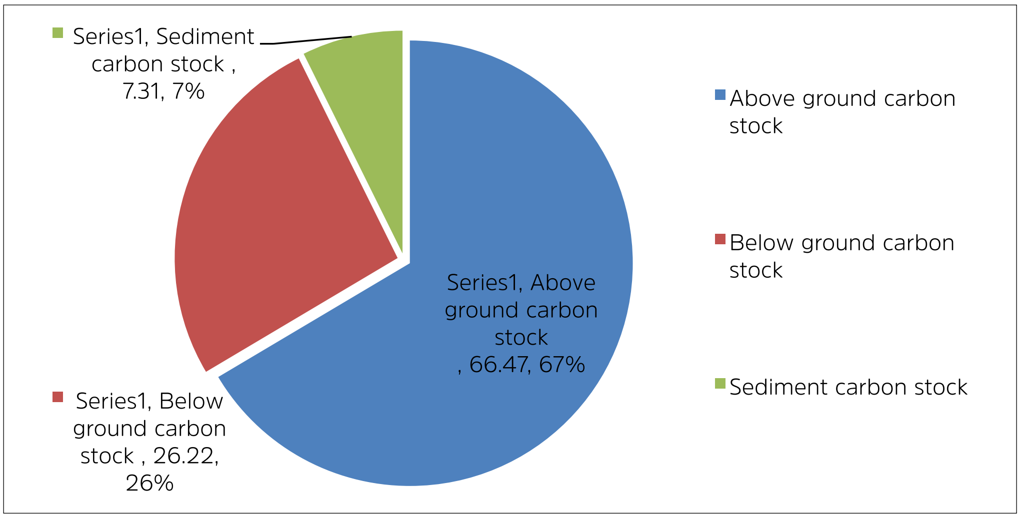


Fig. 2. Percentage contribution of above ground, below ground (root) and sediment carbon stocks of mangrove ecosystem in Muzhappilangad Bay

# Optimum environmental conditions confronting the global threats on coral reef ecosystem in the Indian EEZ

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Coral reefs are one of the most valuable ecosystems of the world and highly productive hotspots of biodiversity. It also acts as facilitators of other reef invertebrates and fishes. Since they support social and economic development of the country, the conservation and protection of coral reefs are important. Coastal marine ecosystems are highly dynamic and include spatial and temporal variability in response to changes in environmental factors. Such changes are of great impact on rate of growth of corals. Light, sea surface temperature (SST), wind and chlorophyll-a are the most important physical factors that determine the growth rate of corals. Variation in SST is the major long term influencing factor. Understanding the growth process and distribution of corals are crucial to study their role in the marine ecosystem and to obtain insight into their susceptibility to changes in the external physical environment. Quantitative observations using Line Intercept Transect (LIT) survey method were conducted at few selected locations of coral reefs in the Indian exclusive economic zones (EEZ) to determine the abundance and the presence of other benthic components in the reef. Increased live coral percentage was witnessed in some of the surveyed islands of Andaman and Nicobar, Lakshadweep and Gulf of Mannar. We used satellite derived SST, wind and chlorophyll-a to validate with *in-situ* data from field surveys. The overall results provide an optimum environmental condition for the growth of coral reefs and the exploration of trends and characterization of system processes. The results could also be useful for the detection of higher resilient and resistant areas of global threats associated with climate change thereby facilitates development of conservation objectives and methods.

# A preliminary assessment of meso and microplastic pollution in a sandy beach in Kerala

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Data on the abundance and distribution of plastic debris are scanty in India and particularly in Kerala despite the increasing global attention towards this emerging pollutant. The current study reports for the first time, the presence of microplastics particles in the sediments of a sandy beach in Kerala, India. In order to evaluate the magnitude of plastic pollution in beaches on a preliminary level, three sites in Fort Kochi beach were selected for collection of sediment samples based on the frequency of activity on the beach, which corresponded to the probability of littering on the beach. Samples were collected and examined for the presence of meso and microplastic debris by sieving through ½" mesh sieve followed by 1/30" mesh sieve. Microplastics below 5 mm size present in the sediment were alternatively extracted based on density separation method. Maximum quantities of plastic particles were recovered from site 1 which was the most frequented portion of the beach. The results of the analysis showed that mesoplastics were present in all the samples which could be differentiated into three size categories of 5mm-10mm, 11mm-15mm and 16mm-20mm. Potential microplastics were recovered from 22 out of 24 samples by sieving and visual sorting method and from 19 out of 24 samples by density separation method, indicating their wide distribution in the beach sediments. The morphology of the meso and microplastics recovered and observed in this study suggested their origin from fragmentation of large plastic debris indicating the use and disposal of plastics as their ultimate origin. Statistical comparison using one-way ANOVA between weights of microplastics extracted by density separation from the three sites showed no significant difference. Considering the large-scale production and use of plastics, necessary abatement measures are required to control coastal pollution due to plastics in Kerala beaches for the protection of the terrestrial ecosystem and its biodiversity.

# Bioremediation of industrial effluent at the source level using aquatic macrophytes

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Kerala is the state in India, which holds the third highest position in the number of small scale industries in the country which is around 2,58,000 and this number is increasing per annum. Even though industrialization and urbanization is considered as the stepping stone to a country's development, the effluents released into the water bodies may lead to unrepairable damage to the aquatic environment thereby affecting the livelihood of the coastal people. The present investigation was done in the Cochin inshore waters (9º 59' 12. 56" N and 76º 16' 20. 74" E) that was extremely polluted due to the effluent discharged into the canal water connecting to the sea through the lake. The chemical parameters showed a wide variation in ammonia content in the effluent water which was found to be very high with a value of 4.05 mg/l with reference to the normal estuarine water which was 0.14 mg/l and was 96% higher in effluent water. Similarly the phosphate and silicate content of the effluent water was about 84.3 and 87.6% higher than the normal estuarine water. The presence of heavy metals like zinc (0.71mg/l) and copper (0.16 mg/l) was also observed in the effluent. Experiment conducted in the laboratory condition using aquatic plants like *Eichhornia crassipes, Pistia stratiotes* and mangrove such as *Rhizophora mucronata* and *Bruguiera gymnorrhiza* for 5 days showed the increase of DO and BOD level with decreasing TSS and nutrients. The absorption of ammonium ion was quite low, ranged from 4.0 -10.5%, rather the toxicity of ammonia was found in the aquatic plant and mangrove used for treatment. The biosorption study was carried out for the removal of heavy metals by column chromatography using seaweed powder of *Sargassum wightti* and *Kappaphycus alvarezi*. *Sargassum* could accumulate the Zinc 17.6 (mg/kg) and copper (1.96 mg/kg) whereas *Kappaphycus* could accumulate 76.06 (mg/kg) of Zinc and 16.64 mg/kg of copper in different effluent collected from the canal and outfall area leaving the elute below the detection level. The main aim of this study is to bring forth a new concept of eco-friendly processes to counter this contamination of water bodies by phytoremediation using various aquatic plants like *Eichhornia crassipes, Pistia stratiotes* and mangrove such as *Rhizophora mucronata* and *Bruguiera gymnorrhiza* and seaweed like *Sargassum wightti* and *Kappaphycus alvarezii* and suggest the industries to implement the method so that the industry will be benefited by a cost effective technology of treatment of their effluent before releasing to the natural environment, reusing the same water in the industry and to protect the fragile aquatic system from pollution besides mining the heavy metals from the bioremediator through phytomining.

# Modeling the biomass of Indian Oil Sardine along south west coast of India using regression model with ARIMA noise

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Climate change alters the natural environmental conditions of marine ecosystems. Such variations are reflected in the abundance of fish in coastal waters. Indian Oil Sardine (IOS), a major commercial fishery resource in the southwest coast of India was taken as a candidate species to study the impact of changes in essential climate variables. Changes in different variables such as chlorophyll-*a* concentration (Chl-*a*), upwelling index, sea surface temperature (SST), precipitation, sea level anomaly (SLA) and wind speed are significantly influencing the abundance of IOS in South Eastern Arabian Sea (SEAS). The changes in optimum level of these variables affect the IOS. Hence in the present study, an attempt was made to find out the relationship between environmental variables and biomass of IOS. Four model combinations were developed utilizing time series data of six environmental variables related to the favourable growth of IOS such as Chl-*a* concentration, upwelling index, SST, precipitation, SLA and wind speed during 1998 to 2015. Standardized catch per unit effort (SCPUE) of IOS from 1998 to 2013 was used for building the model and data estimated were used for model validation during 2014 and 2015. A regression with Autoregressive Integrated Moving Average (ARIMA) errors was used for modeling the SCPUE time series of IOS. During this study, the model combination of SLA and Chl-*a* concentration generated the least Akaike Information Criterion (AIC) value and best fit was used for predicting the SCPUE of IOS. The developed model provides forecasting on IOS resources for decision support tool in climate change related research.

# Indian marine fisheries in the face of a changing climate

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With its sprawling coastline spread over 8129 km and a continental shelf area of 0.53 million square kilometres, India is home to a vibrant and diverse fishing industry, incorporating many modes and types of fishery - from the artisanal to the industrial-involved in the exploitation of a wide variety of species. The last six decades in the industry have shown an unprecedented tenfold growth to a total of nearly 4 million metric tonnes per annum, or around six percent of total global supply. As a result, India's fishing industry employs more than 14 million people directly or in allied industries and contributes more than 1% of the nation's gross domestic product.

National Innovations in Climate Resilient Agriculture (NICRA) is a network project of the Indian Council of Agricultural Research (ICAR) that launched in February 2011 with the aim of enhancing resilience of Indian agriculture to the effects of climate change. CMFRI has been a partner in the NICRA project since its inception and has worked to develop resistance strategies for both the preservation and sustainable usage of the marine ecosystem as well as promotion of coastal resilience and village level resistance to the socioeconomic effects of climate change.

With climate change projected to cause huge upheavals in the world in the coming years, there are likely to be significant detrimental impacts that occur, both to the fishing industry as well as the ecosystem that sustains it. Rapidly increasing sea surface temperatures also bring about an increase in extreme weather events that disrupt fishing industries through the damage and destruction of equipment as well as loss in fishing days. Rising sea levels also threaten vulnerable coastal communities that are often involved in the fishery industry or other allied industries.

Climate change has also been projected to greatly affect the marine ecosystem. Possible impacts that have been forecasted include bleaching of corals and subsequent destruction of habitats due to rising sea temperatures. Rising sea levels may also cause loss of habitats for intertidal organisms and organisms that nest in the intertidal zone such as marine turtles. Beach erosion across turtle arribadas has already resulted in the loss of countless nesting sites, resulting in population collapses in keystone species that have knock on effects throughout the marine ecosystem.

Furthermore, climate change has been shown to have lasting impacts on the phenology and physiology of marine organisms. Experiments undertaken under NICRA have demonstrated detrimental effects on the musculoskeletal structure of species such as silver pompano that develop in elevated ambient temperatures. Rising temperatures have also resulted in shifting migratory patterns, as seen in the movement of Indian oil sardine to the southeast coast in recent years.

This paper discusses some of the impacts that climate change will likely inflict on the fishing industry, as well as follow with a discussion of the resilience options that have been formulated by the NICRA towards mitigating these impacts.

# Increasing natural disasters and climate shocks in Asia and the need for climate action plan for protecting fisheries and aquaculture sectors

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Natural disasters disrupting normal life have been found to increase in Asia, affecting all sectors of populations, rural as well as urban. During the last 120 years (1900 to 2019 (August)) about 5214 natural disasters have occurred in Asia affecting more than 7006 million people and causing damage of an estimated US $ 1.4 x $10^{12}$. With 1607 events forming 30.82% of the total, South Asia, was the worst affected followed by Southeast Asia with 1557 events (29.86% (Fig 1&2). In East Asia there were 1494 events and this formed 28.65% of the total events. However, economic loss was highest in East Asia (75.7%) followed by South Asia and Southeast Asia.

During the 120 year period, of the 17 types of natural disasters ranging from cyclones, tsunamis, droughts, floods, landslides and bacterial/viral diseases, tropical cyclone with 1140 events was found to be the most common followed by riverine floods (Fig 3). Region-wise differences were found in the major type of disasters. While tropical cyclones were found to increase from 11.3 events per year during 1949-1999 to 25.7 per year during 2000 to 2019, the increase in riverine floods was from 5.04 per year to 36.1 per year during the respective periods.

The increase in population especially in low lying areas of coastal regions is also a matter of concern. The extrapolated population counts in low elevation zones for the year 2100 and the percentage of this group have been found to vary in different regions of Asia. The lowest and highest percentage of population living in the low elevation coastal zone (LECZ) in different regions varied and were estimated as East Asia 7.5 % (S Korea) to 53 % (Macao in China), South Asia 1.8 % (Pakistan) to 91.6 % (Maldives); Southeast Asia 2.8% (Timor-Leste) to 55.5% (Vietnam) and West Asia 0.3% (Syria) to 72 % (Bahrain). This has been found to increase since the 1990. The sea level rise in LECZ area also has been found to be vary in different regions ; East Asia 1.97 % (China) to 50.93% (Macao in China); South Asia 2.94 % (Pakistan) to 88.53% (Maldives),

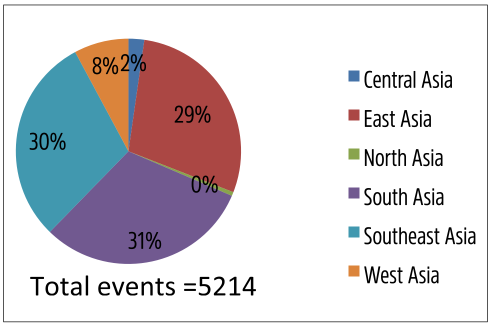


Fig 1 Regionwise occurence (in percentage) of natural disasters in Asia during the period 1990 to 2019

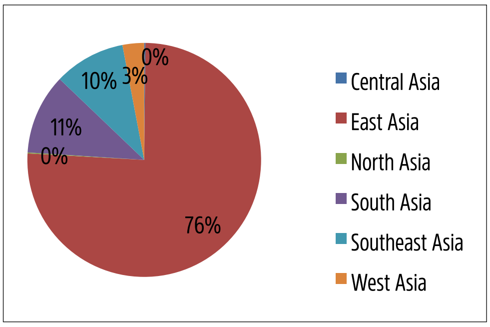


Fig 2 Regionwise total damage (in percentage) caused due to natural disasters in Asia

Southeast Asia, 2.22 % (Timor-Leste) to 25.88 % (Singapore) and West Asia, 0.07 % (Syria) to 54.3% (Bahrain). The number of natural disaster during 2000 to 2019, percentage change in number of disasters and population in major cities is depicted in Fig 4.

Climate shocks are also common now. The Kerala floods 2018 and tropical cyclone Ockhi 2017 were totally unexpected to the people of Kerala and Tamil Nadu along the southern part of India. These led to human causalities, damage to public infrastructure and personal loss to millions of people in these two maritime states. The fishing industry was also affected and the rehabilitation is not yet completely over. The innumerable developmental programs in coastal areas encroaching into wet lands and river basins have exacerbated the impacts of natural disasters and climate shocks.

The present study gives an overview of the types of disasters in each Asian region, the frequency of occurrence and highlights the need to have climate action plans to safeguard the coastal population and support the fisheries and aquaculture sectors across the region.

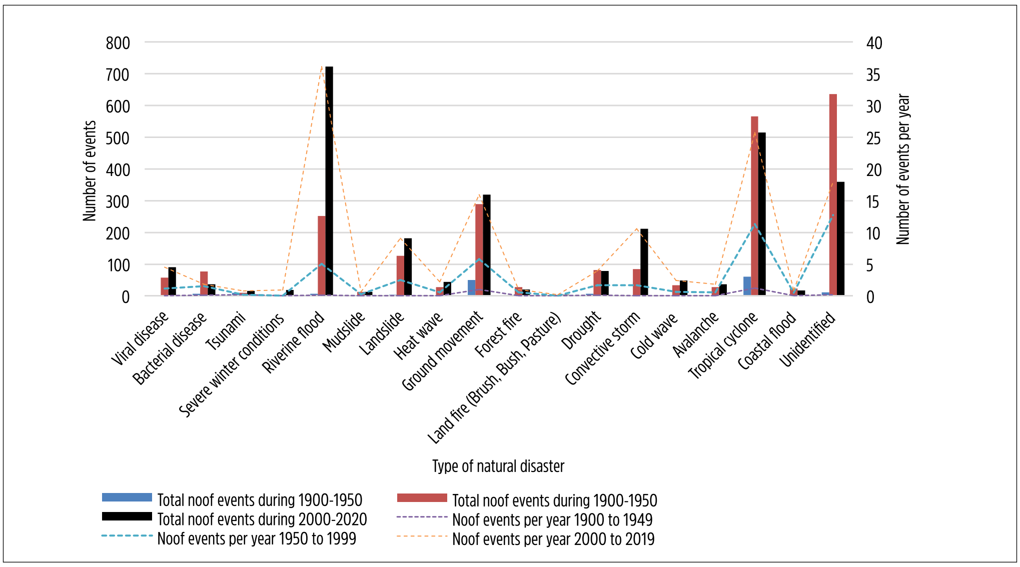


Fig 3. Number of natural disaster in Asia during the period 1900 to 2019

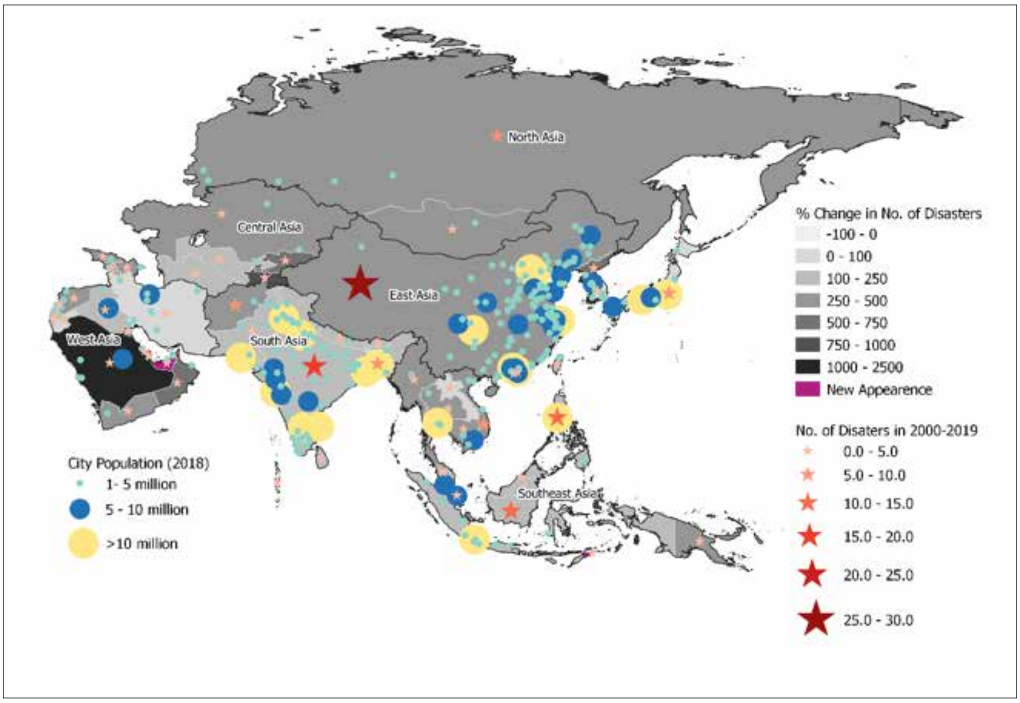


Fig. 4 The number of natural disaster during 2000 to 2019, percentage change in number of disasters and population in major cities of Asian sub-regions. (Data from EM-DAT and CIESIN)

# Mass mortality of *Mactra violacea* along Diveagar beach in Maharashtra

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Diveagar Beach, located in Raigad District of Maharashtra stretches across 4 kilometres in length and at the northern end, small rivulets enter the sea. The surf clam *Mactra violacea* Gmelin, 1791 forms sustenance fisheries along the beach, providing livelihood to bivalve fishers. *M. violacea* burrow in subsurface layer and prefers sandy and silty habitat. Mass mortality of this venerid clam was observed during the initial phase of monsoon, starting from 8 to 18 June 2019 along Diveagar Beach. Simultaneous clam and seawater samples were collected to investigate the probable cause of this phenomenon. Satellite data on Sea Level Anomalies (SLA), mean wave swell period, sea surface current was extracted to arrive at conclusion. Length range of *M. violacea* varied from 22.15 mm to 60.85 mm. Dead clam had higher density per sq. metre (82±13.65) as than dying clams (15±4.2). Stranded dead and dying *M. violacea* individual were spread over 1.5 km stretch of Diveagar beach. Biological investigation shows almost all individual were mature having male to female sex ratio of 1:0.59. Condition Index (CI) based on dry flesh weight and shell cavity volume ranged between 74 to 185.

No abnormality in water quality were observed that could justify the sudden mass mortality of *M. violacea*. Altimeter satellite gridded data computed from all altimeter from 01 May to 30 June 2019 shows sudden rise in significant wave height from 13 cm to 25 cm indicating probable reason to justify the sudden mass mortality of *M. violacea*. Due to increscent nature of waves and repeating and periodic disturbance at sea bottom, clams would be more prone to be carried towards shore and unable to return. In addition to this larger wave, breaking farther from the beach making clams prone for desiccation. Surface ocean current estimates, derived using quasi-linear and steady flow momentum equations also indicates increased current speed from 4 m/s to 9 m/s during mass mortality event along Diveagar Beach.

The present finding emphasizes more fine scale monitoring for frequency, extent and factors responsible for such mass mortality events considering ecological and socioeconomic importance of bivalve resources.

# Assessing the fishery and gear vulnerability to climate change in the multi-species and multi-gear marine fisheries of India

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There are substantive reviews which examined the possible impact of climate change globally on marine fisheries and ecosystems. Indian marine fisheries, vital to the coastal economies and livelihoods and food security of coastal communities, are particularly vulnerable to the impacts of climate change. A review of available literature suggests scarcity of studies on the impacts of climate change on fisheries sector specific to the tropical multi-species multi-gear marine fisheries of India, perhaps with the exception of few studies on the individual species level impact and vulnerability assessments. The direct and indirect influences of climate change drivers will result in changes at different levels of fish harvests and these changes can be expected to be somewhat different across different maritime regions along the coast of India. The relative vulnerability of key species to climate change along the maritime regions of the country has been examined in an earlier study, as a function of exposure, sensitivity and adaptive capacity. In order to identify vulnerable hotspot regions of the country and to predict the vulnerability of Indian marine fisheries sector to climate change, the relative vulnerability of the fishery and harvest methods were assessed using the species vulnerability score developed for various maritime regions of the country and their catch proportions time series. The mathematical expression for calculating vulnerability scores for regions and different fishing gears is

$$V_f = \frac{\sum_{i=1}^{s} \frac{V_i p_i}{\sigma_i}}{\sum_{i=1}^{s} \frac{p_i}{\sigma_i}}$$

where V*f* is the overall vulnerability score for the fishery in the region/gear, is the vulnerability score of the species *i*, is the proportion of the species in the average annual catch in the time series dataset, is the standard deviation in the proportion of catch.

The fishery vulnerability score along the coast of India ranged from 1.26 to 1.80. Among the four maritime regions of India, the fishery along the southeast coast as well as northeast coast were found to be highly vulnerable with a relative vulnerability score of 1.80 and 1.69 respectively. The fishery along the northwest and southwest coasts were moderately vulnerable to climate change impacts with a score of 1.26 and 1.34 respectively. Among the harvest methods across all the regions, the mechanized sector recorded the highest vulnerability score in relation to climate change. The predicted changes in the vulnerability of the fishery and harvest methods under various RCP scenarios were also examined and it is found that both the gear vulnerability and fishery vulnerability across the regions increase under the current harvesting strategies.

# Climate impact on Oil Sardine stock along southwest coast of India: modelling stock biomass dynamics with environment in multi-gear situation

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Oil sardine (*Sardinella longiceps*) is a major fishery resource along the southwest coast of India accounting for more than 19% of the total marine fish landings in the region. A large number of fishers in this region depend on this resource for their livelihood and it is an important food source for meeting the nutritional requirements of economically weaker sections. Changes in climate are expected to influence the spawning and reproduction of fish species. Long term changes in environmental parameters may affect the recruitment of fishes, thereby affecting fluctuations in their biomass. In particular, the larvae of pelagic fishes like oil sardine are highly sensitive to environmental changes and larval mortality rate will affect recruitment of fish into the fishery thus affecting their biomass and availability in the catch. There are fluctuations in its abundance and on many occasions the oil sardine fishery along the region failed leading to social concerns. It is important to examine the effect of climatic changes on the biomass dynamics of this resource to assess its stock and management. With this intention modelling of the stock biomass dynamics of oil sardine along the southwest coast of India by incorporating

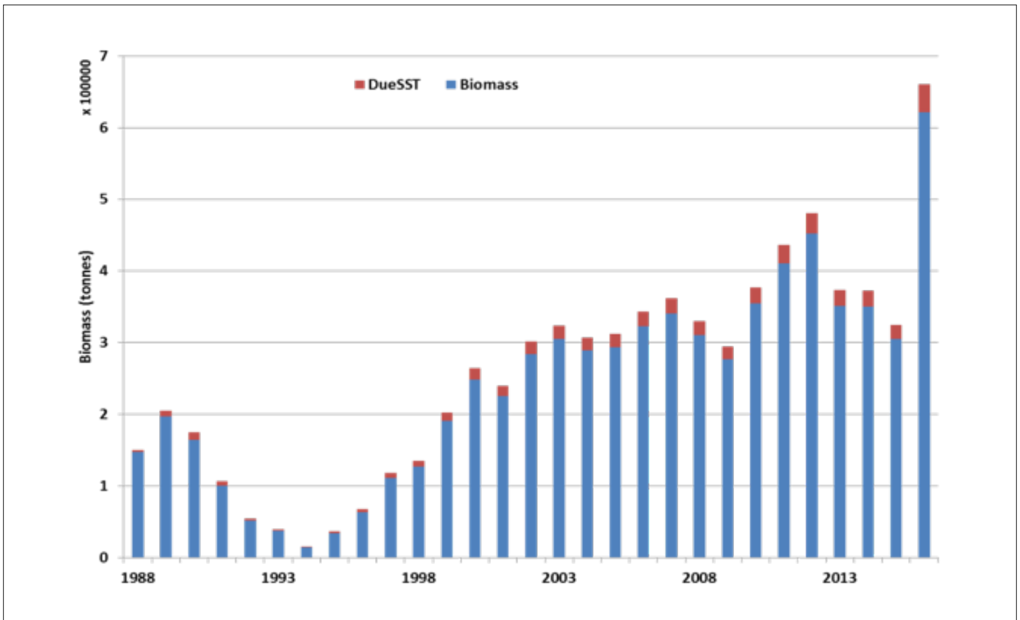


Fig. 1. Effect of SST on the changes in biomass of the oil sardine *Sardinella longiceps* during 1988-2016 along the southwest coast of India.

lagged terms of environmental variables and multi-gear situation into the model using time series data on gear-wise landings and fishing effort obtained from the National Marine Fishery Resources Data Centre (NMFDC) of ICAR-Central Marine Fisheries Research Institute (CMFRI) for the period 1985-2016. The environmental variables incorporated in the model were sea surface temperature (SST) and precipitation (PPT). The SST for the period 1985- 2016 at a resolution of 1x1° were downloaded from Hadley Centre Sea Ice and Sea Surface Temperature data set (HadISST), from ICOADS-NOAA and data on PPT from CPC Monthly Analysis of Global Land Precipitation, v1.0 (0.25° resolution). The impact of variations in these climatic parameters resulted in increase in oil sardine biomass along the southwest coast of India. The results indicate that about 6.3% of the annual additions to oil sardine stock biomass along the southwest coast of India is contributed by variations in sea surface temperature and only 1.1% increment in biomass due to the effect of precipitation.

# Plastic contamination in the sediments of selected beaches of Tuticorin, Gulf of Mannar

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Studies on the quantitative and qualitative estimation of plastic contamination in the sediments of four beaches with varying levels of fisher's intervention and cleaning measures were carried out during 2017-18. Inigonagar beach (St.1- Lat.08047'.450'N; Long.078009'.675'E), Vellapatti Beach (St.4-Lat.08051'.423'N; Long.078010'.009'E), and Vivekananthanagar beach (St.3-Lat.08049'.574'N; Long.078010'.066'E) are intensively polluted due to fishing activities and lack of any cleaning measures. The Pearl City beach (St.2-Lat.08048'.463'N; Long.078009'.777'E) is the only recreational beach with the routine cleaning process.

Sediments were collected from the top two cm at the high-tide mark on the shore of these four beaches, from areas of 50x 50 cm$^{-2}$ in triplicates every month. The collected sediments were air-dried and sieved (1- mm), and the plastic particles collected were sorted size-wise according to the standard procedures as micro- (<5 mm), meso- (5-20 mm), macro- (21- 100 mm) and mega- (>100 mm) debris. The abundances were estimated in numbers and weight per square metre in the sediment. The mean density of total plastic litter contamination was higher at beaches nearer to fishing villages. The plastic litter contamination was maximum in the Inigonagar beach sediments (St.1) on a numeric basis (23±7.6 Nos.m$^{-2}$) and weight basis (4.87±2.76 g.m$^{-2}$). The Vivekanandanagar beach reported being with the second-highest plastic contamination. The recreational Peral City beach recorded with the third-highest numeric density of plastic litters, whereas

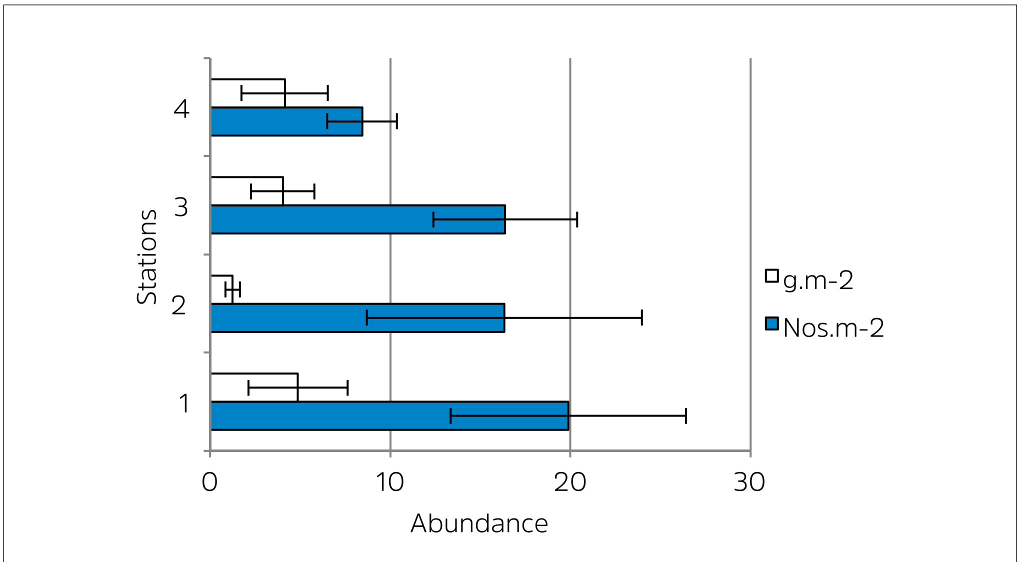


Fig. Mean values of total plastic contamination in the sediments of beaches of Tuticorin (1- Inigonagar beach; 2- Pearl City beach; 3- Vivekananthanagar beach and 4- Vellapatti Beach) the Vellapatti beach though noticed with the lowest litter level on numeric basis, reported to have the third-highest level of plastic litters on a weight basis.

Macro-plastics are the principal litter constituents in the sediments of all the beaches, with the highest percentage of 70.9% were noticed at Vivekanandanagar beach (St.3). At the recreational Pear City beach, the dominance of meso-plastics (41.83%) was noticed. Mega-plastics was found to be the second dominant plastic litter constituent in the sediments of Inigonagar beach, Vivekanandanagar beach and Vellapatti beach. The station wise variation in plastic contamination was not significant (p>0.05). At Vivekananda Nagar beach, and Vellapatti beach sediments the mean density of macro-plastic was highest on both numeric and weight basis. The mean density of micro-plastics is highest at Inigonagar beach sediment on a numeric basis followed by macro-plastics on both numeric and weight basis. At the recreational Pearl City beach, the mean density was highest for meso-plastic. Most of the beaches, the highest level of plastic litter contamination was noticed associated with the windy pre-monsoon season during August and June, which indicated the role of wind in contaminating the beaches of Tuticorin. The significant seasonal difference was noticed in the variation in the density on a weight basis (p<0.001). The study also indicated the need for awareness creation among the fishing community on the ill effect of plastic pollution in the sea.

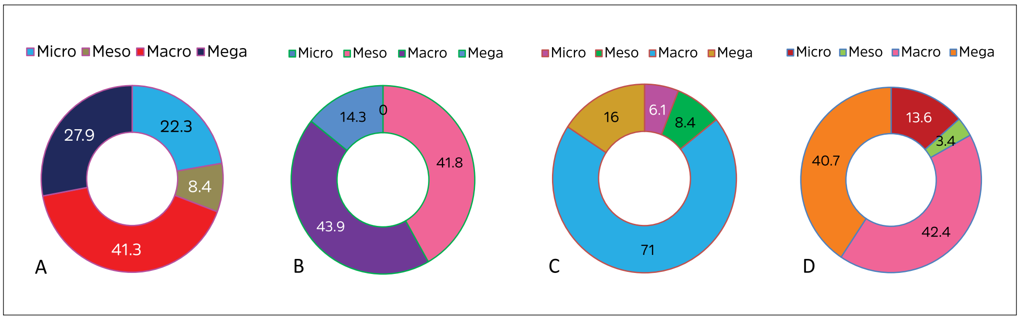


Fig.2 Percentage composition of litter constituents in the beach sediment of Tuticorin
A-Inigonagar beach, B- Pearl City beach, C- Vivekananthanagar beach, D-Vellapatti Beach

# Water and sediment parameters influencing mangrove ecosystem

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Mangaluru (12.87°N 74.88°E) is one of the urban coastal cities in Dakshina Kannada district of Karnataka. It has a population of 5,55,244 (as per 2011 estimated) and area of 132.45 km$^2$. The major rivers Netravati and Gurupur River joins near Bengre and drain into the Arabian Sea. The Netravati River is the main source for drinking water, agriculture, fishing as well as power generation for the regions, Mangaluru, Bantwal, Uppinanagady, Dharamasthala and Ullal. The Gurupur River is a tributary of Netravati, the New Mangalore Port, the Special economic zone industries are situated along its boundary. There are vented dams which regulate the flow of water in the downstream of both Netravati and Gurupur river. Population increase coupled with the destruction of mangrove forest through human activities such as deforestation, conversion of mangroves to agricultural land, sewage discharge and effluent from industries can impact the environment with changes in the water (Hauff *et al*., 2006; Smith, 1992; Lugo and Snedaker, 1974) and sediment quality of mangrove ecosystem. Hence, water and sediment quality parameters were monitored from two sites in Gurupur river a degraded ecosystem in which mangroves were planted and another in non-mangrove area. In addition to this a natural mangrove area in less disturbed habitat with better diversity of mangroves in Hegemadi situated on the banks of Shambhavi river was selected. Principal Component Analysis (PCA) was carried out to ascertain the most important parameters influencing the stations selected in combination as well as separately in mangroves planted area (St-1), a non-mangrove habitat (St-2) and a natural mangrove ecosystem (St-3). Water and sediment quality data were collected for a period of 6 years (2011-2016) on monthly basis from the stations.

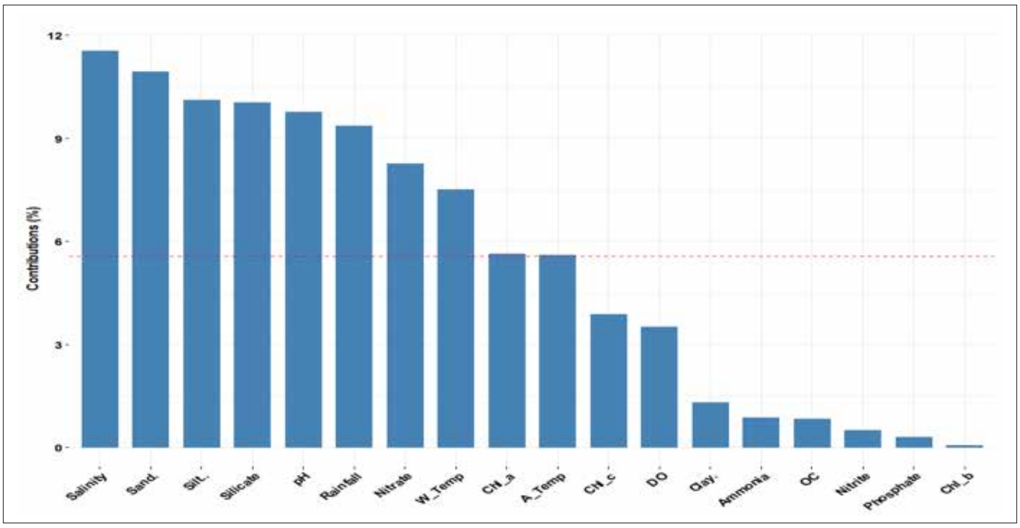


Fig. 1 Percentage contribution of all parameters estimated for the three stations under study.

It was seen that the influence of salinity was the highest in the system and diagonally opposite to that of nutrient silicate, indicating that rainfall and consequent river discharge contributed to the growth of mangroves. Moreover, rainfall, silicate, nitrate and phosphate were correlated. In the natural mangrove ecosystem (St-3) the major contributors were in the order Salinity (24.9%) >Rainfall (16.7%)>Silicate (12.1%)>pH (8.7%)> Chlorophyll c (7.3%)> Nitrate (6.3%)> Chlorophyll a (5.3%)> water temperature (3.9%)> Chlorophyll b (3.3%). In St 1 and St 2 the contribution of Chlorophyll was not observed indicating lesser productivity due to disturbed ecosystem. The percentage contribution of all parameters estimated for the three stations combined is given in Fig. 1. It was seen that pH was observed to be diagonally opposite to rainfall, silicate, nitrate and phosphate in all the three stations indicating that lesser river discharge could negatively influence the ecosystem. The Sand% and Silt % was also observed to be diagonally opposite in all the three stations. A diversity rich mangrove ecosystem had more silt as the roots help retain the turbid water during monsoon. June, July and August were the months observed contributing to the growth of mangroves.

# Bluecarbon assessment of seagrass meadows of the Palk Bay and the Gulf of Mannar

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The term Blue Carbon refers to the carbon stored in sediments from coastal ecosystems such as seagrass meadows, mangrove forests and salt marshes. Seagrass meadows though occupy only below 0.2% area of world's oceans, they are considered one of the major blue carbon sinks that contribute indirectly to climate change mitigation as they are estimated to burry 27.4 Tg carbon per year. Gulf of Mannar and Palk Bay harbour 13 species of seagrass species dominated by *Cymodocea serrulata* and *Syringodium isoetifolium*. Blue carbon stock of Gulf of Mannar and the Palk Bay were computed from the organic carbon content of sediment core taken from the meadows. The results of this study are discussed in the light of climate change mitigation and emphasising the need to conserve these underwater meadows.

# Climate change related natural disasters and strategies for management in the coastal marine ecosystems of India-a review

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Climate change is a term that refers to major changes in temperature, rainfall, snow and wind patterns lasting for decades or longer. Both natural and human causes contribute to climate change. Global and regional changes have been observed in chemical composition of the atmosphere, earth's surface temperature, precipitation, extreme climatic events and rise in sea level. These have caused changes in biological, physical and socio-economic systems. Climate change does not take place overnight; it takes a long time for the climate to change. The future changes in atmospheric composition (GHG's) and climate are inevitable with increases in temperature and some extreme events, and regional increases and decreases in precipitation leading to increased risks of extreme events, like cyclone, floods and drought. The larger changes and rate of change in climate, the more in the adverse effects, predominate with developing countries being the most vulnerable. Human causes include burning fossil fuels, cutting down forest and developing lands for farms, cities and roads. These activities release greenhouse gases into the atmosphere. Natural causes include changes in the earth's orbit, sun's intensity, circulation of ocean and volcanic activity. Although the earth climate has changed many times throughout its history, the rapid warming seen today cannot be explained by natural process alone. Human activities are increasing the amount of greenhouse gases in the atmosphere and there by warming the earth. This will certainly amplify the climate processes. Since the industrial revolution, mankind has been burning fossil fuels for transport, domestic purposes and to produce electricity on a large scale that has caused worldwide air and water pollution as well as greenhouse gases produced and thereby threatening all life on planet- earth.

These climate changes impacts both coastal marine ecosystems and altering patterns of living coastal marine fishery resources, availability, affecting human population, livelihood and health. These impacts in their turn affect human development on human communities and natural coastal marine ecosystems for instance changes in land use patterns that lead to deforestation and loss of biodiversity. These changes affect species distributions, ocean productivity and timing of seasonal biological events. Coastal planning and management are constrained largely by a lack of information, data and analysis about the interaction between development activities and the coastal environment. It is necessary for integrated coastal zone management (ICZM) process to identify during strategy planning, the critical coastal habitats that merit high degree of protection. This presentation reports on a framework of indicators of potential vulnerability developed at the socio-economic and ecosystem level for coastal India. The concern with coastal vulnerability is really a concern for the negative outcomes that may result from the combination of development pressures and stressed ecosystems. This paper deals with the climate change related natural disasters and vulnerability assessment in the coastal marine ecosystems of India.

Natural disasters are intimately connected to the process of human development. Disasters triggered by natural hazards put all the developmental gains at risk. At the same time, the development choices made by individuals, communities and nations can pave the way for unequal distributions of disaster risk. About 75% of world population lives in areas at least once earth quakes, tsunamis, tropical cyclones, floods, droughts have occurred. The major climate change related natural disasters such as tsunamis, tropical cyclones, floods, droughts, landslides, forest-fires are responsible for 94% of the deaths triggered by natural disasters. The results are summarized in this paper in global terms and for each hazard type and found that disaster risk was found to be considerably lower in high income countries than in medium and low-income countries. The four phases of natural disasters management, such as preparedness, mitigation, response and recovery are discussed.

# First report of vertebral deformity in the caudal region of narrow-barred spanish mackerel, *Scomberomorus commersoni* (Lacepède, 1800), from India

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Among the four available seer fishes (*Scomberomorus commersoni, S. guttatus, S. lineolatus*, and *Acanthocybium solandri); in* Indian coast, *S. commersoni* (30170 tonnes) is a significant contributor. An abnormal specimen of seer fish was collected from the Versova landing centre from the Mumbai, Arabian Sea. The collected specimen was compared with the typical 46 specimens, which showed similar morphological characters except the vertebral deformity near the caudal region (Lumbar portion). The deformed fish was radiographed, which showed a distal malformation about 40th to 49th amphicoelomic vertebral bone. The possible reasons behind the skeleton anomaly could be the degradation of the aquatic environment by chemical pollution. With this finding, the authors aim is to highlight the requirement of critical monitoring of the marine environment and also for the identification of the specific reason(s) that causes these anomalies. The current paper is the first of its kind to report severe vertebral column deformity particularly in the caudal region (combination of Scoliosis-Lordosis-Kyphosis) in a large Narrow-barred Spanish mackerel (*S. commersoni*) specimen from India.

# Phytoremediation of inshore water of Mangaluru

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In the last few decades, pollution associated with point and non-point sources have been identified as serious threat to water quality around the world. The demand for water in Mangaluru city of Dakshina Kannada district is 162 MLD and the present supply is 140 MLD. There are a number of industries situated in the vicinity of the coastal areas that discharge the treated effluents into the Arabian Sea. At present the total effluents discharged is 80 MLD which is expected to increase with more industries to be commissioned in the Special Economic Zone (SEZ) and the expansion of the existing industries. Fresh water is most precious commodity on earth, so to protect this, either it should be reused or recycled. Industrial utilization of fresh water is very high compared to the domestic use, thus it is time to think how to utilize the same water after repeated treatment and making the industry as zero discharge.

Phytoremediation techniques are a low-cost alternative for wastewater treatment and in many cases, it could be coupled with nutrient recovery and biomass production (Srivastava *et al*. 2008).

Treated industrial waste water is partly re-used and remaining is discharged into sea at 650 m seaward at Surathkal and Chitrapur. The effort of our studies is to make it more environmentally friendly so that the whole water of the industry can be reused.

*Eicchornia crassipes* is a highly adaptive aquatic plant and recently it has been identified as a means of producing biofuel. It is resistant to pest and diseases and naturally grows in stagnant ponds and lakes. It has high cellulose and lignin content per unit volume of dry matter.

Trials were conducted by using this plant in treated effluent water obtained from industries before letting out into the open ocean. Standard methods were used to estimate the reduction in nutrients and pollutants. There was reduction in phosphate, ammonia, cyanide and sulphide level in the treated water within 6 days of treatment. Atomic absorption spectrophotometer for heavy metal analysis of the leaves showed an increase of 40% and 55% in Cu and Cd uptake. It was evident that the plant is capable of absorbing heavy metals in addition to reduction of nutrients. This will help the industry to further reduce the available nutrient load and heavy metals from the treated effluent if passed through the *Eicchornia* bed so that it can be reused in the industry. More experimental trials need to be conducted with better facilities to standardize the method and design structures for large scale treatment for effluent of water.

# Bioremediation efficiency of detritus degrading bacteria and microalgae in the treatment of municipal sewage effluents of Tuticorin

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The untreated gallons of effluents discharged from Tuticorin Municipal sewage unit into the sea are causing irreversible damages to the coastal ecosystem of the area. An experiment was conducted to compare the bioremediation efficiency of a detritus degrading bacteria and micro-algae species in degrading the environmental contaminants of the sewage effluent released into the Tuticorin coastal waters. Four micro-algae species (*Nanochlropsis salina, Chlorella salina*, *Isochrysis galbana* and *Pavlova lutheri)* were used in the first experiment. For the second experiment, a commercial product of detritus degrading, euryhaline bacteria *Bacillus cereus* "Detrodigest" was used at three levels of dilution (undiluted, 50% and 75%) and both the experiments were conducted for ten days. One set of control comprising effluent with aeration, were arranged for comparing the results. All the treatments were arranged in triplicates. The analysis of various parameters of the effluent sample was conducted before the start and after the completion of the experiments.

In the first experiment, there was a considerable reduction in the ammonia concentration from the initial toxic level of 2.478 $mg.L^{-1}$ to the non-toxic level was observed in all the treatments. The maximum reduction of 96.8% was seen in the micro-algae *P. lutheri* treated sample where the ammonia was reduced to the lowest mean value of 0.079±0.002 $mg.L^{-1}$. High level of nitrite concentration (38.05$\mu g.ml^{-1}$) was noticed in the initial sample, which was found to decrease in all the experimental setup, with the highest reduction (97.34%) noticed in the aerated sample. The initial high value of phosphate (8.67 $\mu g.ml^{-1}$) has found to be lowered to the minimum of 2.985 $\mu g.ml^{-1}$ with 65.57% decrease in the *P.lutheri* treated sample followed by *I. galbana* treated sample. Similarly, the highest percentage of reduction (93.18%) in silicate was noticed in the *C. salina* treated samples. The one way ANOVA also indicated a highly significant difference in the variation of ammonia, phosphate and silicate levels between the treatments ($p<0.01$). The experiment indicated that microalgae species are efficient in the reduction of ammonia, phosphate and silicate content in the effluent sample.

In the second experiment, the highest percentage of reduction in BOD (100%) and the toxic level of ammonia (92.16%) were seen at bacterial treatment with 50% dilution with seawater. The highest percentage of reduction in phosphate (23.16%) was noticed at undiluted bacterial treatment without aeration. There was a reduction in silicate level observed with the highest percentage of reduction (21.9%) was noticed with the aerated undiluted treatment. The one way ANOVA indicated a significant variation in the level of ammonia, phosphate, silicate between treatments ($p<0.01$). In general, the experiment ascertained the utility of the bacterial strain in reducing the deleterious parameters like BOD, NH at 50% dilution level and the PO and SiO level without dilution.

Both the experiments indicated the role of aeration in enhancing the DO, salinity and pH of the treatment sample. Hence it is recommended that the sewage effluent can be treated first by aeration followed by mixed algae and detritus degrading bacteria for efficient reduction in the toxic level of BOD, ammonia and nutrients like phosphate and silicate of the sewage effluent.

# Impacts and prospective resilient strategies for Indian marine fisheries sector to climate change

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Mounting climatic pressures inscribes its multi-dimensional profound impacts on species phenology, resource distributions, catch compositions, habitat dynamics and coastal livelihoods along the Indian coast. To clearly understand these issues as well as to suggest adaptation and mitigation strategies, a national level project, NICRA was initiated by ICAR in 2011. Under this scheme, coastal zone-wise studies on climate change impacts have been carried out and several resilient strategies were accordingly evolved. Shift in spawning seasons as well as diet composition changes has been recorded for several key commercial fish stocks such as Indian mackerel, Indian oil sardine and threadfin bream. A negative correlation with SST was observed for marine plankton species, fish eggs and molluscan spat/larvae which have implications on fish larvae survival and growth. Conversely, fish larvae, shrimp post-larvae and other crustacean (crab and squilla) larvae were positively correlated with sea surface temperature, indicating survival potential in spite of climate change stress. However, as the fish larvae and shrimp post-larvae were found to be distributed very near to the shoreline, the coastal pollution including runoffs through excessive precipitation could negatively impact the fish and shrimp larval survival and growth. As a first of its kind, zone wise vulnerability of total 68 species of pelagic, crustaceans, demersal and molluscs were assessed in the context of climate change and the species were accordingly classified. Habitat preference was discerned for Indian mackerel with reference to oceanographic variables such as SST, Chl, sea surface height, salinity, mixed layer depth. Climate change driven shifts in the abundance of marine planktons affects the relative importance of various prey items in the diet of Indian mackerel. Increase in the occurrence of phytoplanktons in the diet as well as a change in prey composition of zooplanktons in the diet has been observed. Mackerel is an opportunistic feeder that changes its preference according to the availability of the resources and energy demands.

The relationship of oceanic variables to Indian Oil Sardine fishery studied with GAM Models show significant results. The trend of CPUE, effort and catch for 2020-2100 under two RCP scenarios 4.5 and 6.0 strongly suggest an initial increase till 2050 followed by a dramatic decrease in the abundance and distribution of IOS towards 2100 under both scenarios. The chances of occurrence of jelly bloom could be attributed to the favourable salinity range less than 35.5 ppt and bottom sea temperature below 20.5°C. Life cycle assessment of several fishing harbours revealed that highest emissions were contributed in harvest phase. Elucidation of carbon sequestration potential of seaweeds and mangrove ecosystems were done to explore the blue carbon reserves. Coast wise oceanographic variable model projections for Indian Ocean were obtained for 2020-2100 along with validation of real time data sets, which shall be an efficient tool in developing fisheries management plan for each coastal state. Coastal community empowerment was done through participatory approach of technology demonstrations such as low cost cages, all weather moorings, Integrated Multi Trophic Aquaculture and Integrated fish-paddy farming. As a socio-economic resilience strategy as well as first national instance by a fisheries institute, a multi-vendor e-commerce website and mobile application was developed with facilitation of direct sales and market linkages for the fishermen communities. Technical guidelines have been extended to implement the similar system to the Govt. of Himachal Pradesh for inland fisheries. As an ecological resilience strategy, a national resilience framework for fisheries and wetlands has been developed for continuous monitoring as well as to provide real time advisories of national wetlands. Accordingly, in collaboration with Space Applications Centre (SAC)-(ISRO) a mobile application for field level wetland data collection and associated web portal as a national wetland repository has been developed. Climate smart village development programs were successfully done with technology demonstrations, eco-restorations and integrated farming approaches. Scientific interventions could play a vital role to negate the impacts of climate change and to enhance the climatic resilience of Indian marine fisheries sector.

# Vulnerability assessment of coastal villages in Thiruvallur district of Tamil Nadu

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Thiruvallur district lies between 12°15'-13°15' N and 79°15'-18°20' E in north Tamil Nadu. The total geographical area of the district is 3422 sq. km, with a coastal spread of 498 sq.km along an 80 km long coastline. Marine landforms along the coast include lagoons, mangrove swamps, salt marshes, estuaries, creeks, sand dunes and beach terraces. The Pulicat Lake adjoining the Bay of Bengal is a brackish water hot spot, supporting rich diversity of flora and fauna. There is a high extent of coastal erosion and accretion along this coast. Marine fishing is a major occupation in 39 villages of the district. Social development in the coastal villages is relatively slow, even while industrialization is taking place at a faster rate in many of the sites. An assessment of vulnerability of the coastal villages was done in order to provide primary information on ecological and social issues to be addressed to allow progressive development of the coastal communities against the background of changing environmental conditions and climate change.

Based on preliminary interaction with village leaders and primary village-level pilot surveys along coastal Thiruvallur, twenty-one villages were identified for the study. The villages identified can be grouped into three clusters - those around the Pulicat lake, which face few negative impacts of anthropogenic activities and are better off with respect to fishery resources, but face threats to environment and habitat alterations and lack sufficient developmental progress, those that are slightly interior with very poor social and economic standards and relatively low livestock and fishery resources, and those that are south of the Pulicat lake, which are better positioned environmentally but face the brunt of industrialization. Questionnaire-based household surveys were conducted across 30-50 households in each village.

Vulnerability indices were derived for environmental, fishery, social, economic and development drivers based on indicators and sub-indicators of climate change following the method given by Patnaik and Narayan (2005). From the responses obtained, it was observed that socio-economic development is directly impacted by loss of livelihood and sustenance sources due to habitat destruction and dwindling of fishery resources, caused by anthropogenic and natural causes. The indirect impact relates to low education and employment opportunities due to lack of proper infrastructure facilities. Lack of marketing channels is a major drawback for fishing activities.

All the respondents opined that habitat loss and reduction in fishery resources are the major reasons for declining fishery. 81% ranked habitat destruction and 79% ranked decline in fish availability as major factors of immediate concern, while 76% ranked industrialization and pollution. 64% ranked lack of development programs as a cause for concern. Natural calamities and climate change were ranked by 61% and 53% of the respondents as major issues. Karunkali village was most vulnerable, followed by Koraikuppam, Ernavurkuppam and Kattupallikuppam. Vairavankuppam, Lighthousekuppam and Goonankuppam were the least vulnerable. The overall vulnerability index for coastal Thiruvallur was obtained as

0.701, indicating high vulnerability. The major issues to be addressed are interventions for protection and restoration of coastal water habitats, reducing pollution in coastal waters, improving infrastructure facilities for social development and living standards, and, awareness generation drives among the coastal communities for effective participation in working towards these goals.

Table 1. Vulnerability ranking of 21 villages in Thiruvallur district, Tamil Nadu (arranged by location, from north to south along the coast)

| Village | Vulnerability Index | Vulnerability Rank |
|---|---|---|
| Kottai kuppam | 0.735 | 10 |
| Thoniravu | 0.767 | 8 |
| Senjiamman Nagar | 0.758 | 9 |
| Kulathumedu | 0.726 | 12 |
| Jamilabath | 0.769 | 7 |
| Goonan kuppam | 0.568 | 19 |
| Sempassipalli kuppam | 0.592 | 16 |
| Lighthouse kuppam | 0.535 | 20 |
| Nadu kuppam | 0.574 | 17 |
| Arangan kuppam | 0.571 | 18 |
| Vairavan kuppam | 0.534 | 21 |
| Sattan kuppam | 0.655 | 15 |
| Korai kuppam | 0.821 | 2 |
| Karunkali | 0.833 | 1 |
| Kattupalli | 0.795 | 4 |
| Kalanji | 0.794 | 5 |
| Ernavur kuppam | 0.798 | 3 |
| Kattu kuppam | 0.791 | 6 |
| Nettu kuppam | 0.672 | 14 |
| Thazhan kuppam | 0.702 | 13 |
| Kathivakkam chinna kuppam | 0.733 | 11 |

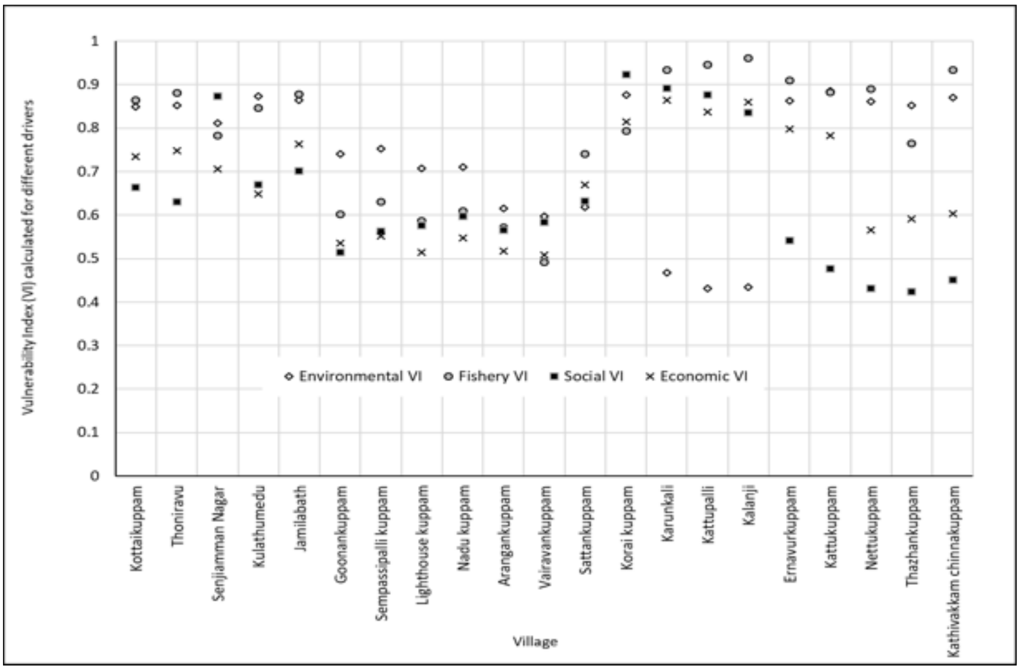


Fig. 1. Vulnerability indices calculated development drivers for 21 coastal villages in Thiruvallur district

# Ocean and climate information forecast services: Evaluation by the fisher folk communities off the east and west coast of India

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The frontiers of science and technological advancements are increasingly perforated towards incorporating ways of understanding the phenomenalvariability on earth with response to climatic events. The noticeable life-threatening weather and climate conditions such as cyclones, storms, flood and droughts pose serious risks to the poor indigenous coastal communities in the tropical regions. In comparison to the South-Asian countries, India tends to be high in range, experiencing the impact of the vicious spiral paradox between disaster, environment sustainability and coastal vulnerability. Inorder to address this discourse on the role of scientific and technological advancements in climate and weather forecast for the coastal communities, Ministry of Earth Sciences (MoES) and its branching institutions provides the ocean state information to all the seafaring communities, including the fishermen, Indian Navy, Indian Coast Guard, merchant and passenger shipping agencies, offshore oil and gas exploration agencies and research organizations.

In serving this purpose, the current work was focused on gauging the extent of adoption of the scientific weather forecast services towards the fisher folk communities across the two coastal states of India. The work aims to ascertain on the future needs of the fishers in terms of technology development and dissemination. About 1240 individual respondents were surveyed along the two coastal states, Andhra Pradesh (523 respondents off the East coast) and Kerala (717 respondents off the West coast) of India. Multistage random sampling method was used for selecting study locations and sample size to be surveyed in each coastal state/union territory. The primary data collection was carried out through questionnaire survey from each fisher respondents during the months of June 2018 to December 2019. 47% are registered users of the INCOIS services and 53% are non-registered users reliant on the ocean information services from other weather forecast departments and organisations. Age, experience in fishing, interest in fishing, type of fishing sector and crafts and gear were used as the socio-economic attributes to enumerate the extent of adoption and usage of the INCOIS services. Most of the INCOIS services users belong to the age bracket of 20-40 with 20-40 years of experience in mechanized and motorized fishing sector are registered users under INCOIS dissemination units, since 2011. From the ocean state forecast services provided, the most received and used services are climate-weather predictions, wind and current and cyclone forecast. Other services provided include Temperature, Oil-spill, Tsunami events and Potential Fishing Zone advisory, which were not highly adopted by the fisher communities of both the coasts. These services are said to be inconsistent in periodicity, timeliness and reliability in the surveyed coastal regions of India. Ocean state forecast information is received on daily and weekly basis to the users as audio advisory services through audio telephone helplines from MS-Swami Nathan research foundation and Reliance TRUST foundation. Indigenous traditional knowledge (ITK) was also widely used for weather and climate predictions. Fish harvesting, fish catch and weather prediction using water colour, wind-tide directions, appearance of fish shoals, mammals, and sea-snakes were reported by the fishing communities. Fishers Friend Mobile Application is mostly used only for geo-referencing fishing location whereas other usages of the app are not adopted by the fishers. Advisory services in the frontal areas, species-based PFZ, geo-referenced wind, tide and current pattern predictions, geo-referencing validation, signal and battery related problems with using gadgets/mobile phones, real-time predictions, forecast services through SOS service and satellite phones are the recommendations and suggestions reported by the fishing communities of the region. In the same context, the approach of fisher folk communities towards using scientific forecasts coupled to their indigenous traditional climate related forecasts are now in its embryonic stage of development. In light of this background, this article concurs with studies that propose a framework for theintegration of ITK with scientific forecasting for improved seasonal predictions in order to reduce climate risks and vulnerability.

# Significance of physico chemical parameters on the health of a coastal ecosystem with special reference to the distribution and abundance of phytoplankton in the coastal waters of Dakshina Kannada

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Marine environment is a complex ecosystem which is influenced by physical, chemical and biological processes. Plankton is of great ecological and economic importance as it is at the base of aquatic food webs and fisheries. Further, the primary production by coastal phytoplankton contributes almost 15% of global oceanic production (Walsh 1991). They also serve as bioindicators of water quality including pollution. The phytoplankton distribution and its relation to the physico chemical characteristics of the coastal waters of Dakshina Kannada was studied. Sampling was made for a period of two years during 2014 and 2015. The Netravati-Gurupura Estuary is formed by the confluence of two rivers Netravati and Gurupura and bordered by Ullal and Bengre villages on one side and the Mangalore fishing harbour on the other side. This estuary has been facing great damage due to sand mining, excessive siltation, discharge of sewage effluents and improper drainage due to mangrove afforestation. These in turn concentrate the pollutants in the wet lands resulting in enrichment of waters. Alteration in physico-chemical factors of the estuarine habitats can lead to various ecological consequences like changes in plankton species composition, blooms of phytoplankton as well as have an impact on the nearshore waters.

Two near shore stations and two stations from the Netravali Gurupura Estuary were studied during the period. Pronounced variations in the primary production, phytoplankton standing stock (chlorophyll a), physico chemical parameters such as water temperature, pH, salinity, dissolved oxygen and nutrients were observed at the selected stations, which includes. Standard analytical methods (APHA, 1981) were used for the estimation of physio chemical parameters and was indexed for water quality (USEPA 2006). The phytoplankton samples collected from the selected sites were enumerated and identified by referring standard manuals and publications. The diatom genera that were noticed in coastal waters of Dakshina Kannada includes, the centrales, *Bacteriastrum* sp., *Biddulphia* sp., *Campylodiscus* sp., *Chaetoceros* sp., *Climacodium* sp., *Coscinodiscus* spp., *Cyclotella* sp., *Ditylum* sp., *Eucampia* sp., *Guinardia* sp., *Lauderia* sp., *Leptocylindrus* sp., *Melosira* sp., *Planktoniella* sp., *Proboscia* sp., *Pseudosolenia* sp., *Rhizosolenia* spp., *Skeletonema* sp., *Stephanopyxis* sp. *and Triceratium* spp. Among the pennales, *Asterionella* spp., *Bacillaria* spp., *Fragilaria* sp., *Gyrosigma* sp., *Navicula* sp., *Nitzschia* sp., *Pleurosigma* spp., *Pseudo-nitzschia* sp., and *Thalassionema* spp. *Among the* dinoflagellates *Noctiluca* spp. was dominant during the receding time of the south west monsoon. Several blooms were observed during this period due to sudden variations in the physio chemical parameters. A massive bloom of *Lauderia* sp. was observed during the month of February 2015 with a cell number of 4.2 x $10^5$cells/L. This was also followed by a bloom of *Coscinodiscus* sp. in the nearshore waters off Dakshina Kannada in April 2015.

The water quality index indicated that the near shore waters of Dakshina Kannada (Fig 1) had still not deteriorated, and showed an improving trend in 2015 than 2014 and more months with good quality water in the post monsoon season. But this was not the case in the estuarine waters (Fig 2) as it showed poor water conditions in both the years. This indicates that the estuarine waters are in great threat and if appropriate measures are not taken it can effect the near shore waters.

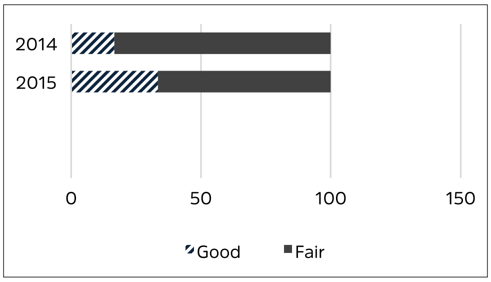


Fig 1. Water quality Index of the nearshore waters off Dakshina Kannada (%)

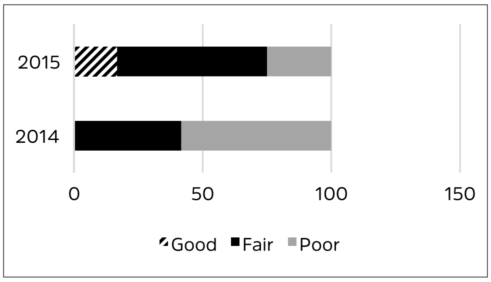


Fig 2. Water quality index of Netravati Gurupura estuary during 2014 -2015 (%)

# Seagrass vegetation in certain parts of Chilika Lake during early winter season

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Chilika Lake, the largest brackish water lagoon in Asia is situated on the east coast of India between 19° 54' N and 19° 28' N latitude as well as 85° 67' E and 85° 35' E longitude and extends from southwest corner of Puri and Khurdha districts to the adjoining Ganjam district in the state of Odisha. This lake forms the base of livelihood security for 0.2 million fishers and 0.4 million farmers living in and around the lake besides, the feeding and breeding grounds of nearly 0.8 million water fowls mostly migratory during winter. The area of the lagoon varies between 1165 and 906 sq. km during the monsoon and summer respectively.

Observations during October - November 2017 and 2019 from 11 locations in the Chilika Lake showed dominant submerged vegetation of *Potamogeton pectinatus* in all the observation sites. Even though the water salinity was within 9 psu, patches of seagrasses such as *Halophila ovalis*, *Halophila ovata*, *Halophila beccarii* and *Halodule uninervis* and Halodule *pinifolia* were found growing in shallow regions of the lake. Organic carbon content in the meadow sediment have also been estimated and correlated with the vegetation type.

# Carbon footprint of fishing practices of Lakshadweep

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Lakshadweep group of islands has a meagre 32 sq.km. geographical area available for all their needs, including housing. However, availability of 4200 sq.km. of enchanting lagoons ideal for Responsible Tourism Programmes, 20,000 sq.km. of Territorial Waters and 4,00,000 sq. km. of EEZ encompassing 6 submerged sandbanks and 3 coral reefs which hold high-value fishery resources, particularly tunas and reef fishes. This makes it one of the richest Island territories of India. The conservative potential estimate is about 1.0 lakh tonnes. Further, 0.63 million tonnes of deep-sea squids are also available in Lakshadweep sea and the contiguous Central Arabian Sea. But, as per 2004-16 estimates, the average annual landings in the Islands is 10,175 t only (Fig. 1). The catches taken away and landed elsewhere are also to be properly accounted for. Together the total is far below the potential.

The judicious utilization of fishery resources

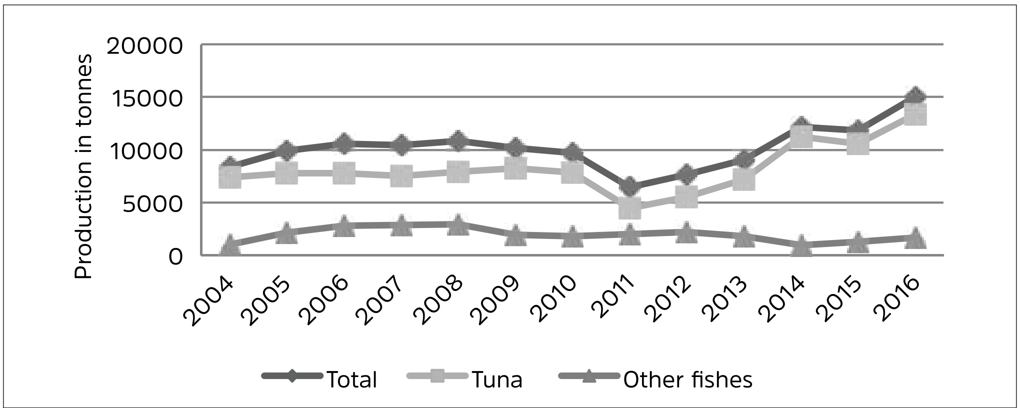


Fig. 1. Fish production trend in Lakshadweep during 2004-16

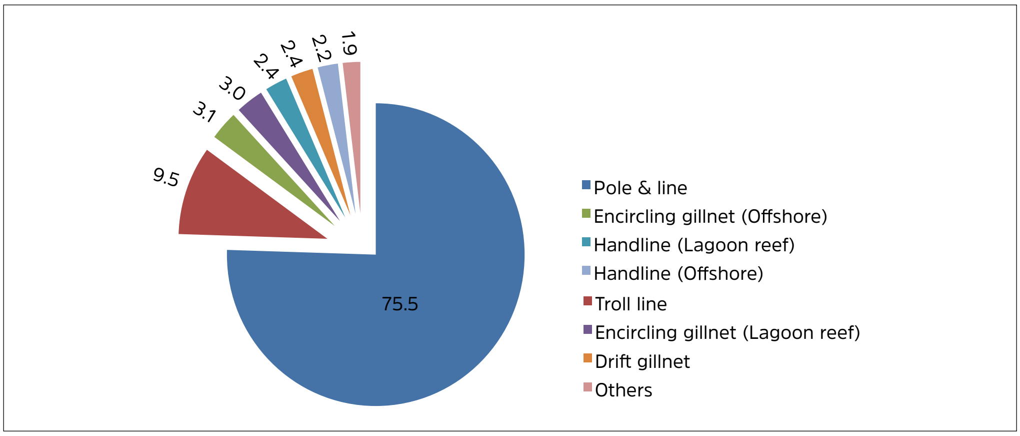


Fig. 2. Gear-wise average percentage contribution of 2004 - 16 landings

is critical for sustainable developments. The technical knowledge, particularly exploitation techniques is imperative for designing fruitful developmental programmes. The viable action plans need to be designed at the earliest.

The fishing practices in vogue, scantly known to technocrats, are highly eco-friendly both towards ecosystem and stocks. The industrial and indiscriminate fishing are not practiced. The artisanal subsistence fisheries are mostly restricted to the islands alone. The paper envisages to describe the major fishing practices and their carbon footprints. Of the 21 methods, the eight most important ones which account for >98% of the total catches and auxiliary live bait fishing are briefly described.

The motorised Pablo boats and the traditional stitched *Thoni/Odi* with OBMs are the crafts employed. Flat-bottom career boats, *Burkas*, are occasionally utilized for fishing. The crafts are platforms aiding the gear operations. Pablos use diesel and OBMs kerosene for the operations. The fuel consumptions were different for different gears due to durations of operations.

Pole & lines (*shoorakkole*) most productive gear made using 9-15' bamboo poles, monofilaments and special barbless hooks are very effective for shoaling pelagic fishes. The scouted shoals are chummed using live baits synchronised with water spraying for creating feeding frenzy. The fishes grabbing the hooks, being moved amid the shoal are lifted quickly. They gets unhooked automatically and the process is repeated. The average gear-wise percentage contribution is illustrated as Figure 2.

The carbon footprints of Pablos were worked out based on the average values of 2014 and 2015 of Agatti, Andrott, and Minicoy fishing operations. The values exhibited wide variations even for the same gear due to the types of engines, duration of operation, fish density in the areas, etc. (Table 1).

The values for Pole & Lines at Agatti, Andrott, and Minicoy were 0.42, 0.64 and 0.34 kg CO per kg fish respectively. Troll Line values varied from 0.92 to 1.43 kg CO/kg fish between the islands. The variations were very wide for same gears. Hence, estimated the averages for different gears for getting more realistic value and the same is presented (Figure 3).

The Lakshadweep fishery is at subsistence level. All fishing practices are considerably at low levels of $CO_2$ emissions. The emissions can be further minimised by reducing the scouting time of pole & line operations. The upliftment of massess is very essential for their existence. Judicious utilisation of fishery resources and eco-tourism promotion by designing appropriate development schemes are the most ideal option for achieving the target.

Table 1. Island-wise, gear-wise ande average $CO_2$ values (in kg/kg fish)

| Islands | DGN | H&L-OS | P & L | LL | H&L-LR | HRP | TL | EGN-OS |
|---|---|---|---|---|---|---|---|---|
| Agatti | 0.45 | 0.41 | 0.42 | 0.50 | 0.75 | 0.83 | 1.43 | 3.40 |
| Andrott | 0.24 | 0.55 | 0.64 | 0.50 | 0.62 | GNO | 1.10 | 0.49 |
| Minicoy | GNO | 0.18 | 0.34 | GNO | 1.12 | GNO | 0.92 | GNO |
| Average | 0.34 | 0.38 | 0.47 | 0.50 | 0.83 | 0.83 | 1.15 | 1.94 |

GNO-Gear Not Operated

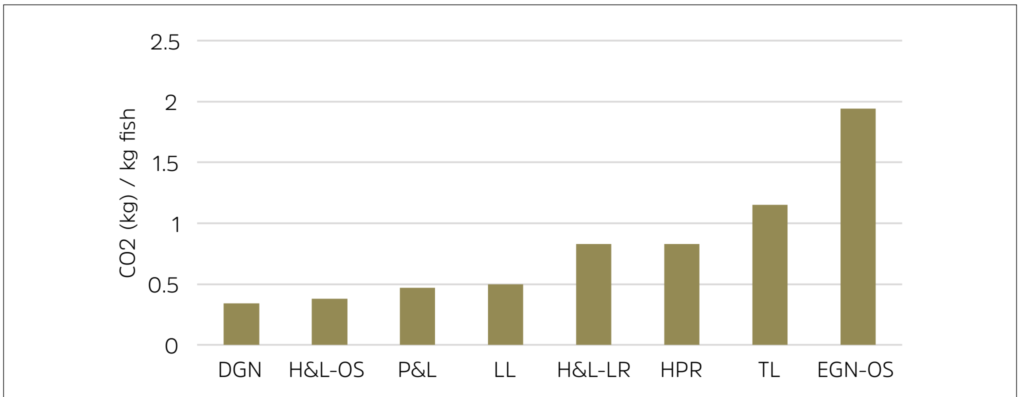


Fig. 3. Average (2014 & 2015) $CO_2$ values of eight fishing practices of Lakshadweep

# Coastal industries of India on GIS platform: Way forward to work for development and environmental sustainability

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India has a coastline of 7500 km with nine coastal states, two union territories and two island systems. Coastal length of mainland is 5421.6 km whereas islands have 2094 km. There are 13 major and 34 minor ports in India besides many industries which are located in the coastal India. The major industries are oil and refinery, ship building, ship breaking, salt, Chemicals and fertilizer, cement, Iron and steel, Rare earth, and many mineral and pharmaceutical industries. Most of the industries are having their own effluent treatment plant with zero discharge of water to the natural environment. Still it is a matter of concern that many of the industries, harbour, fish market, domestic sewerage, agricultural runoff located in the vicinity of the coast discharge the effluent directly to the natural waters like canal, backwater, lake and river system which drains most of the pollutant to the sea leading to eutrophication. Over 80% of all marine pollution originates from land-based sources. Municipal waste water is one of the single major polluting agents in India. Mangrove is found to be a important bio barrier to absorb many of these pollutant but according to the Government of India report (1987) India lost 40% of its mangrove area during the last century. The east coast of India supports agriculture, aquaculture activities and few industries where as the west coast of India supports many industries and the activities are going to increase. This project was aimed to develop a platform for collaboration with coastal industries; municipality and other stakeholders to develop suitable bioremediation technology to deal with the effluent (treated/untreated) generated which is being released to the natural water bodies. All the centres of CMFRI are working on priority basis on the regional issues related to coastal pollution through bioremediation which will be helpful for growth and development with environmental sustainability.

# Water quality based ecosystem grading of a coastal village in the Vembanad Lake system, Kerala, India

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The coastal ecosystems are impacted by anthropogenic activities and habitat of most of the estuarine resident and migratory fauna are getting degraded. The studies conducted by Central Marine Fisheries Research Institute (CMFRI), during the past two decades have shown that the water quality in the industrial area of Vembanad Lake is being affected. The present study aimed at monitoring and grading the aquatic ecosystems of Mulavukad, a coastal village in the Vembanad Lake system so that suitable site specific micro level environment management plan could be developed for solving the issues of environmental degradation and to improve the resource status and for effective utilization of aquatic systems.

Samples were collected from 43 locations covering different usage categories *viz.* open estuary, shrimp farms (operational and non operational), inland water bodies, canals running through populated areas and mangroves. Water quality was assessed based on selected physical, chemical, biological and microbiological indicators using standard methods during post-monsoon (October-December 2017). The data set for evaluation of the ecosystem was selected from these water quality parameters based on PCA analysis. The selected parameters were scored using linear scoring function and these scores were combined into a normalized ecosystem index reflecting the system's overall health. The ecosystems were categorized as poor, fair, moderate and good based on <25$^{th}$, 25$^{th}$-50$^{th}$, 50$^{th}$-75$^{th}$ and >75$^{th}$ percentile values of the normalized ecosystem index obtained in the study area.

Ecosystem grading based on the index revealed that 35% of the estuarine region and 50% of active shrimp farms surveyed were in 'Good' condition (Fig. 1 and 2). Around 33% of abandoned farms have good production potential in terms of water quality. Mangroves showed only fair water quality in 75% of the stations due to the presence of coliform bacteria (Fig.3), inland waters being good in 16.67% stations (Fig.4) and canals with good water quality being 12.5%.

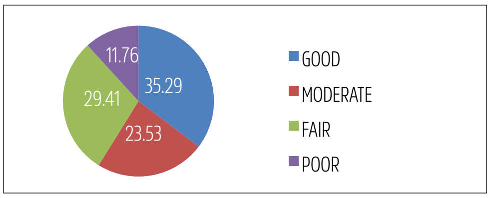


Fig. 1 Ecosystem Grading of Estuary

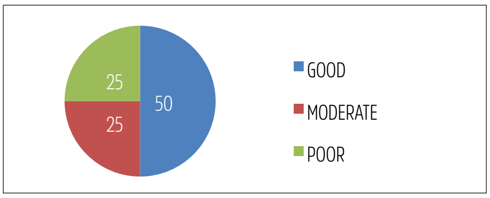


Fig. 2 Ecosystem Grading of Active farms

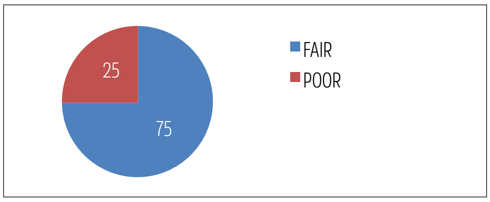


Fig. 3 Ecosystem Grading of Mangroves

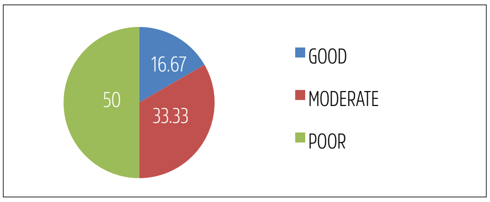


Fig. 4 Ecosystem Grading of Inland waters

# Impact of plastic litter - a quantitative and qualitative investigation in selected mangrove distributions, Kerala, India

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Mangrove forests possess an incredible biodiversity and the ecosystem services they provide include food, shelter and nursery to number of species. The services they contribute to human are also valuable as their capacity to protect us from natural disasters namely shore line stabilization, carbon sequestration and many more. But, today the developmental pressures caused by growing human population seriously impacts this fragile ecosystem resulting in its degeneration to a great extent. Apart from the pollution caused by thermal, agrochemical, heavy metal and oil spill, one of the burning issues which results in its imbalance today is the accumulation of non-degradable plastic litter, which gets entrapped in the root system caused due to mismanaged waste disposal. The partially emerged root system of mangroves forms an effective filter that attenuates wave energy and turbulence and may possibly trap objects transported by currents, like floating plastic objects. (Horstman *et al.*, 2014; Norris *et al.*, 2017). This results in preventing gas exchange and releases harmful chemicals associated with plastic materials.

The study for assessing accumulation and quantification of non-degradable litter was conducted in the selected mangrove fringes of Ernakulam district. Twelve stations were fixed for the survey, six on the southern side of bar mouth (Kannammali, Kandakadav, Kumbalangi, Kumbalam, Nettoor, Panangad) and remaining on the northern side (Valllarpadam, Panambukad, Mulavukad, Puthuvyp, Njarackal and Mangalavanam).

Fig.1 A view of the Mangrove area of Kumbalangi eco-tourism village

Fig 2. Accumulated Litter in the mangroves of Nettoor, adjacent to Maradu vegetable market.

For macro litter sampling, visual census survey was conducted in these locations with a 1x1 $m^2$quadrat and the number and type of items present were counted, to estimate the abundance as per UNEP (2009) guidelines. The observed litter quantities were raised to a 10 sq. m area and classified to give litter codes based on their material composition (PL) and their form (Remote Litter Class, RLC).

Sediment samples were taken with a Van Veen grab, in triplicate for estimating the microplastic abundance in the area. Grab samples were processed as per NOAA protocol (Masura *et al*., 2015).The micro plastics were size fractionized after extraction and categorized as per their shape, colour, dimension and material composition. Identification of the recovered plastics were validated with Fourier transform infrared spectroscopy (FT-IR).

Environmental parameters like water salinity, temperature, pH, total suspended solids, dissolved oxygen and biochemical oxygen demand of the selected sites were also analysed. Sediment characteristics like pH, oxidation reduction potential, salinity, soil texture, and abundance of benthic fauna were also estimated.

To study the impact of plastic litter on benthic community on controlled conditions, a simulation experiment was designed and conducted in two selected mangrove soils, one at Mangalavanam and the other at Njarackal. Double layered woven plastic sheets of size 2mx 2m were laid above the substratum in triplicates, in both the locations, with proper mooring, simulating a situation similar to settling of macroplastic in mangrove area. Sediment sampling was done every third month for a period of one year, for assessing, the impact on abundance on micro plastics and benthic faunal community structure and other ecological changes.

The survey indicated that the accumulation of macro plastics and bundled solid domestic waste were more, where anthropogenic accessibility was high. Macroplastics were found to be entrapped in the root system resulting an anoxic condition and subsiding the aesthetic look. Protected areas like Mangalavanam and Puthuvup (Fisheries station) were seen almost clean since public access to these locations are restricted.

The study revealed that, there is statistically significant variation in micro-plastic content across different locations with maximum plastic count from Kumbalangi and Panangad locations ($F_{(1,114)} = 1.397$, $p<0.05$). Simulation experiment indicated statistically significant reduction in benthic communities ($F_{(1,19)} = 4.613$, $p<0.05$). Details of the survey and the simulation experiment along with recommendations for healthy mangrove ecosystems are presented.

# Water quality index to assess the health of coastal environment of Mumbai coast

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The present work deals with assessment of seasonal water quality index of selected locations along the coast of Mumbai city, which is one of the most polluted in the country as far as coastal environment is concerned. The seasonal Water Quality Index (WQI) was assessed as per methodology prescribed by Central Pollution Control Board (CPCB) using basic surface water parameters viz., pH, BOD (mg/l), DO (%) and Faecal Coliforms (MPN/100ml) measured at ten different stations in the creek and near shore areas along the coast of Mumbai, Maharashtra during the year 2018. The monthly water quality parametric information is presented as an index that express the temporal health status of the given sampling location (Table 1). WQI score between 63 to 100, 50 to 63, 38 to 50 and 38 & less is graded as good to excellent, medium to good, bad and very bad respectively. Initial two categories marked as class A & B and designated as non-polluted, however later two categories marked into group C and D, E and remarked as polluted and heavily polluted. Monthly occurrence of different category of water quality Index of selected stations indicated that out of 36 creek observation 86% falls under 'bad' to 'very bad' category and rest 14 % observations under 'medium to good' category. Water quality of Mahim Creek reported to be polluted throughout the year followed by Versova and Gorai Creek. In case of near-shore stations nearly 20% observations recorded as polluted and others as non-polluted category. Being highly populated and industrialised city, coastal waters of Mumbai are under severe pollution threat and about 50% of the observations recorded under 'Polluted' category. The main cause of poor water quality in creeks is associated with discharge of semi treated sewage, urban runoffs and illicit discharge of industrial effluent. Thus, the WQI could be an efficient and effective way for rapid interpretation of multi-parametric data to a single composite number. Further, it could be a good measure for categorizing ideal water quality and compare the health status of particular aquatic environment, which is imperative in water resource management and planning for coastal zones.

Table.1 Water Quality Index (WQI) for selected stations along the coast of Mumbai (January to December 2018).

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| January | 47.4 | 37.8 | 55.9 | 57.7 | 49.9 | 57.2 | 53.4 | - | - | - |
| February | 56.5 | 35.4 | 47.2 | 56.7 | 57.2 | 50.7 | 59.9 | 67.5 | 61.1 | 72.5 |
| March | 47.4 | 39.1 | 46.9 | 54.8 | 60.7 | 62.8 | 71.4 | 58.4 | 65.2 | 67.3 |
| April | 40.0 | 47.3 | 58.5 | 45.8 | 47.5 | 43.6 | 54.0 | - | - | - |
| May | 38.1 | 39.9 | 49.7 | 47.7 | 50.1 | 60.8 | 49.9 | - | - | - |
| June | 44.1 | 47.3 | 53.8 | 58.1 | 54.8 | 60.6 | 60.8 | - | - | - |
| July | 43.2 | 41.2 | 45.6 | 64.8 | 59.0 | 62.1 | 67.5 | - | - | - |
| August | 53.1 | 42.1 | 34.3 | 59.6 | 66.2 | 66.3 | 57.1 | - | - | - |
| September | 40.2 | 36.2 | 45.1 | 53.5 | 51.2 | 48.3 | 49.9 | - | - | - |
| October | 37.2 | 42.7 | 44.7 | 51.9 | 66.0 | 62.9 | 57.9 | - | - | - |
| November | 35.5 | 33.1 | 40.3 | 54.2 | 61.7 | 45.2 | 48.4 | - | - | - |
| December | 40.5 | 47.0 | 49.0 | 59.7 | 51.4 | 52.5 | 61.8 | - | - | - |
| Station Name | Versova | Mahim | Gorai | Apollobunder | Verosva | Mahim | Juhu | 10m | 20m | 30 m |
| Sub Basin | Creek stations | | | Nearshore stations | | | | Sea stations | | |
| Basin | Coastal | | | | | | | Sea | | |

# Biogenic reef builders and colonisation of sediment recyclers - a post-tsunami phenomenon in inshore waters of Kancheepuram district, Tamil Nadu

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While several studies have highlighted changes in faunal diversity and fish catch along coastal Tamil Nadu after the tsunami which hit the coast in December 2004, a phenomenon which went unnoticed was the distribution of tubiculous polychaetes and associated macrofauna (crabs/mussels) in the inshore waters, until frequent reports by the fishermen in Kancheepuram district, Tamil Nadu. Bottom set monofilament nylon gill nets are often deployed in sandy bed sub-tidal areas at 3-5 fathoms in fishing villages in Kancheepuram district, for crabs, flatfishes and shrimps. Catches at Kovalam, Alamarai, Panayur periyakuppam, Panayur chinnakuppam and Kadalur chinnakuppam villages have often been found to include pieces of rocks made of sand, which are in fact sand tube colonies of reef-building and sediment convertor marine polychaete worm belonging to the family Sabellarididae. It has been observed that over time these sandy stones have grown bigger in size and are forming reef patches along the shallow coastal areas supporting very good fishery of crabs, soles and croakers.

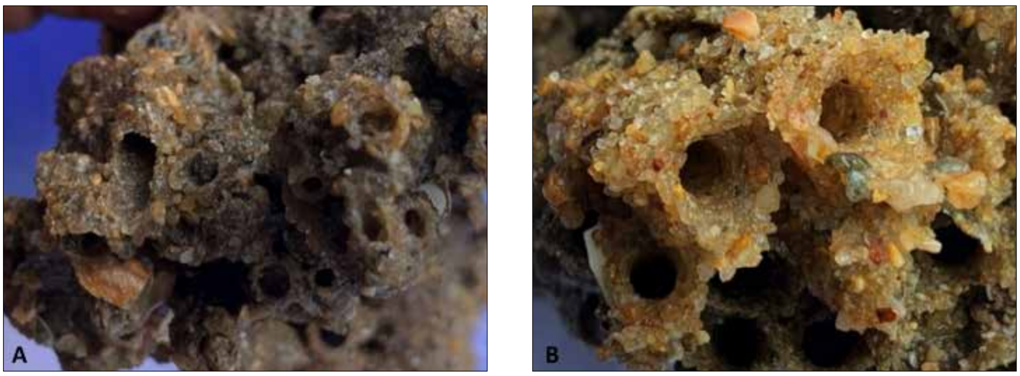


Fig.1. Honey-comb worm clonies from (A) sub-tidal area off Kovalam, and (B ) grown in laboratory

Fig.2. Baby sand castle worm

Fig.2. Juvenile worm forming a new tube

Post-upwelling observations in August 2019 indicate that the patches at Kovalam, Alamarai, Panayur periyakuppam and Panayur chinnakuppam extend over a few metres to a kilometer in radius. Found in coarse sandy bed areas, the patches support colonies of other polychaete worms like the onuphids and pectinarids. Other associated fauna are nematodes, caridean shrimps, portunid crabs, flatheads, soles, cnidarians, echinoderms, goatfishes, gobiids, snappers and juvenile groupers. This has triggered intensified fishing efforts in the last one year. The catch rates of crabs *Portunus sanginolentus*, *Charybdis natator* and other portunids crabs has increased by at least three-folds, with CPUE averaging 200 kg for *P. sanginolentus* and 50-100 kg for *C. natator* during September-November 2019.

A few of these sand tubes or the worm colonies, and the onuphids and pectinarids were held in captivity inside substrate based recirculatory tanks in the Kovalam Field Laboratory of CMFRI to observe growth and behaviour of these worms. A gradient of sediment types and granular sizes were provided to test the selectivity of the material for building the tubes. The sand castle worms showed a preference for yellow sand grains over shell grits and fine white coralline sand. However, bits of plastic were also taken in occasionally. In contrast the onuphid worms predominantly chose bivalve shell grits. They too picked up plastic bits occasionally. Interestingly, plastic ropes and threads were also found in the sandy rock colonies retrieved from fishing nets. Organic fibres were found in onuphid and pectinarid tubes. All these worms respond to organic content in the sediment.

The reef building sand castle worms build a protective tube from sand, with a robust adhesive secretion, and colonise, forming a rock-like reef with a honey-comb appearance when viewed laterally. The colonies are built up with gregarious settlement of larvae which can metamorphose into adults worms only on contact with an existing colony. These reefs assemble alongside hard substrates or rocks to form reef patches. These colonies are found to thrive even in harsh intertidal environments like barmouths with high wave action and organic load. When exposed, they close the entrance to the tube with a setaceous operculum. Crabs and perches are found to prey upon these worms.

Reports from the Pacific coasts of California, USA and Baja California, Mexico suggest that they can be found in densities of nearly 30,000 individuals per sq.m, and can turn over a 3-5" sediment bed of similar dimension in a year, several times, thus enabling recycling of minerals and nutrients back to the water column. These benthic ecological engineers thus build reefs out of sand particles, altering sediment distribution, faunal settlements, water flow and other physical and ecological processes in the area.

# Do fishes consume plastics? If so, are they always dangerous?

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Plastics have tremendous advantages and utility in the present world but its indiscriminate discard creates a pathway to water bodies and eventually forming a threat to aquatic organisms. The large plastics (macro plastics) can degrade and become smaller meso or micro plastics which can be ingested by fishes and invertebrates. Low density plastics (eg. Poly propylene or polyethylene) are dominant in the top layers for a certain period of their entry, may suffer biofouling causing it to sink gradually. High density plastics (PVC, Polyester and polyamides) usually sink to the bottom. Macro, Meso and Micro polymers selected for the study were polypropylene, polyethylene and polyvinyl chloride

Plastic ingestion can happen both intentionally or accidentally depending on the foraging strategy of the animal: some predatory fish might mistake plastic for food and filter-feeders might ingest them unintentionally while feeding.

In order to understand this process in a better way a laboratory experiment was designed with fishes of two size groups (length 8±2cm and 15±2 cm) for a period of two weeks in triplicate under controlled conditions. Experimental fish selected was *Tilapia nilotica,* collected from the grow-out ponds of Krivigyan Kendra, Njarackal, Kerala. Fish after transportation were stocked in FRP tanks and acclimatised for one week before the commencement of the experiments, and then transferred to experimental glass tanks in the laboratory. 10 % of the water was renewed on daily basis and mild aeration was provided. The Dissolved oxygen and Ammonia levels were continuously monitored throughout the rearing period.

A basal feed was formulated with 36% crude protein and 7% lipid, which is in compliance with the nutrient requirements of tilapia. Plastic particles namely, polypropylene beads of an average size of 4cm which comes under the category of macro plastics were incorporated with feed ingredients and hand pelleted to form a coating of the feed with the bead. Thin sheet of poly ethylene, cut into a size group below 20 mm which falls under Meso plastics, with a known level were also mixed to feed ingredients and extruded to thin pellets. On the third trail, micro plastics (fine PVC powder) with a known percentage inclusion were incorporated with feed ingredients and mixed thoroughly in a Hobart mixer, homogenized and pelletized with a Hobart pelletizer. All the feeds thus formed were dried above ambient temperature and stored. The proximate composition of the prepared feed was also determined.

Large sized fish groups were fed daily with plastic coated pellets and on critical observation it was found that fishes will spit out the bead after consuming the entire feed. Similar observation was found in polyethylene sheet mixed feed pellets also. The intake of micro plastic incorporated feed, upon feeding to both the size groups, showed a positive response, but most of the microspheres got expelled through faeces' within a period of 48 hours to post exposure. However it cannot be generalised, as several studies have already reported about the ingestion of plastics in marine habitats and its consequences thereafter.

The study reveals that every organism will have a tendency to sense their food in the natural habitat. But when consumed unintentionally, it can result in the possibility of intestinal blockage, physical damage, histopathological alterations etc. In addition, leaching of chemicals released from plastic can interfere with fish health.

# Impact of effluent discharge on physico-chemical characteristics of coastal water in Veraval, Gujarat

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Veraval harbour has increased levels of contaminants due to the high volume of effluents discharged, from the nearby industries and have ultimately resulted in environmental problems. There are around 90 industries actively engaged in fish processing in GIDC and harbour areas of Veraval. These industries directly release waste water into the Veraval harbour. The accelerated increase in the input of effluents discharge to the marine systems is a major threat to the integrity of marine ecosystems. The present study investigated the impacts of effluent discharge on the physico-chemical characteristics of coastal waters along the coast of Veraval. Four sampling stations were selected for the studies were harbour region, bar-mouth region, coastal water and offshore waters. In situ data were collected for monsoon months (June-August), withdrawal monsoon months (September-November), winter (December- February) and summer (March-May) in the year 2018-2019. The key environmental factors considered in this study include temperature, pH, dissolved oxygen, ammonia and biological oxygen demand. A significant difference was observed between the stations (*p<0.05*) for dissolved oxygen, BOD and ammonia concentration. High concentration of BOD was observed in harbour (28.54-35.55 mg/l) and bar-mouth regions (25.55-28.09 mg/l). High ammonia concentration was also observed in harbour (13.63 mg/l) and bar mouth stations (8.35 mg/l). By comparing the concentration with the water quality class-SW-IV Waters (For harbour Waters), the Veraval harbour is highly polluted with organic matter from the effluent discharge releasing from nearby industries., The harbour are found to be an ideal site for waste dumping for the industries, due to the greater water depth and distance from land. The harbours are connected with the seas and hence the organic loads from the fish processing plants are released in the open seas. The open oceans have capacity to dilute, transport and disperse wastes and associated pollutant because of their large volume and free exchange of water, but the continuous flow of organic loads makes open seas more vulnerable to the impact of waste disposal in the Veraval coast. A cumulative action plan is required with high volume treatment facility for the treatment of wastewater from the nearby industries.

# Effects of intra-annual patterns of coastal upwelling index (cui) and Chlorophyll on abundance of Oil Sardine along the southwest coast of India: A decadal approach

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Upwelling as an oceanic phenomenon is greatly responsible for increased primary productivity in oceanic waters.Coastal as well as oceanic areas having high primary productivity serves as a feeding ground for larvae and adults of various plankton feeding fishes such as Oil sardine. Approximately 25% of global marine fish catch comes from five major upwelling areas around the world which occupies only 5% of total oceanic area. In case of Arabian Sea, Southwest coast of India is also believed to be an important region of coastal upwelling among various upwelling regions in the Arabian Sea. The intensity of coastal upwelling along SW coast is comparatively lesser than the major upwelling areas in Arabian sea like Somalia and Oman coast but it significantly contribute approximately 30% of total marine catch of India. Understanding the influence of coastal upwelling dynamics on pelagic fish catch like Indian oil sardine were so long as a area of interest for research. Various attempts were made to understand the relationship between the various oceanic environmental parameters like Sea surface temperature (SST), Rainfall or Monsoon, Primary productivity, Tidal patterns, Sea level anomalies etc. and pelagic fish species as it is greatly affected by these parameters. In the current study, we madean attempt to study the relation of environmental parameters and pelagic species mainly Indian oil sardine. For this study, we used remote sensing monthly data of environmental parameters i.e. Chlorophyll-a, Coastal Upwelling Index (CUI) from online public domain and landing data of oil sardine from ICAR-CMFRI for time period 1998-2013. We divided the area of SW coast in 15 grids and each grid were analysed separately. Grid No 1 to 8 represents Kerala state, grid No. 9 to 14 Karnataka and grid No. 15 were for Goa. Time series of environmental parameters and landing data were done which were also analysed with the cross correlation to find lag between the high intensity and abundance of catch. Out of 15 grids, 10 were found significant. When CUI were cross correlated with Oil sardine then, in Kerala, highest correlation were observed in Ernakulum (grid 4) (r = 0.34) at lag -5. In Karnataka, highest correlation in Dakshina Kannada grid 10 (r = 0.48) at lag -6 and in case of Goa it found negative correlation. When chlorophyll-a were cross correlated with oil sardine, grids were not shown significant observable pattern but showed approx. (r = 0.22) (r = 0.30) at lag +2 and +3 in4 grids. This irregularity prompted us to calculate the seasonal anomalies of CUI, Chlorophyll-a and Oil sardine. Seasonal anomalies showed observable patterns in which high CUI were observed throughout the SW coast during monsoon season, high chlorophyll-a were observed during post monsoon season and high oil sardine landing during post monsoon. Finally, we found that the seasonal analysis shows more observable results than monthly analysis.

# Identification, growth and toxicity of a bloom forming Dinoflagellate isolated along the coast of India

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Harmful blooms of microalgae as well as causative taxa are increasing in global oceans, including Indian Ocean. They constitute a great threat to the ecosystem and public health, including socioeconomic development. The genus *Prorocentrum* is highly ubiquitous and many of them are reported as bloom forming organisms from different parts of the world, including the coast of India. A strain of the genus *Prorocentrum* was isolated and cultured under laboratory conditions of 25 ± 1°C temperature and 66μmol quanta $m^{-2}$ $s^{-1}$ light intensity using gf/2 medium. The species was identified morphologically using light and scanning electron microscopy and using molecular techniques. Toxin production and toxicity of growing culture were also evaluated using LC/MS and *Artemia salina* assay respectively. The isolated organism was identified as *Prorocentrum lima*. Okadoic acid, a potent toxin with m/z ratio of 704.5 was detected in analyzed sample. The impact of crude extract of *Proroentrum lima* was experimented on *Artemia* and the results are described.

# Concentration of $^{210}Po$ in the yellow fin tuna *Thunnus albacares* (Bonnaterre, 1788) from the southern coast of india

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Marine fishes are reported as potential bioindicators since they try to accumulate the target radionuclide from surrounding waters in to their tissues. Regular monitoring of radionuclides in fishes assumes greater importance due to their significant contribution to natural radiation dose and understanding the radiological sensitivity of the fishes. Many studies have shown that the anthropogenic radioactivity in most fish species was moderately low and the main dietary contribution to the internal radiation dose is naturally occurring radionuclides, especially $^{210}Po$. The present study was focused on quantifying the level of $^{210}Po$ in yellow fin tuna and radiological dose to human beings established.

Tuna samples were collected from fish landing centres (Idinthakarai, Uvari and Parangipettai) along the southern coast of India (Fig.1). Muscle tissues were isolated from bones and the pooled muscle tissues were oven-dried at 105°C, homogenized and analysed. A portion of 10 g dried fish muscle tissue sample with 0.2 Bq $^{208}Po$ tracer was acid-digested using a mixed solution of $HNO_3$, $H_2O_2$ and HCl. Polonium was

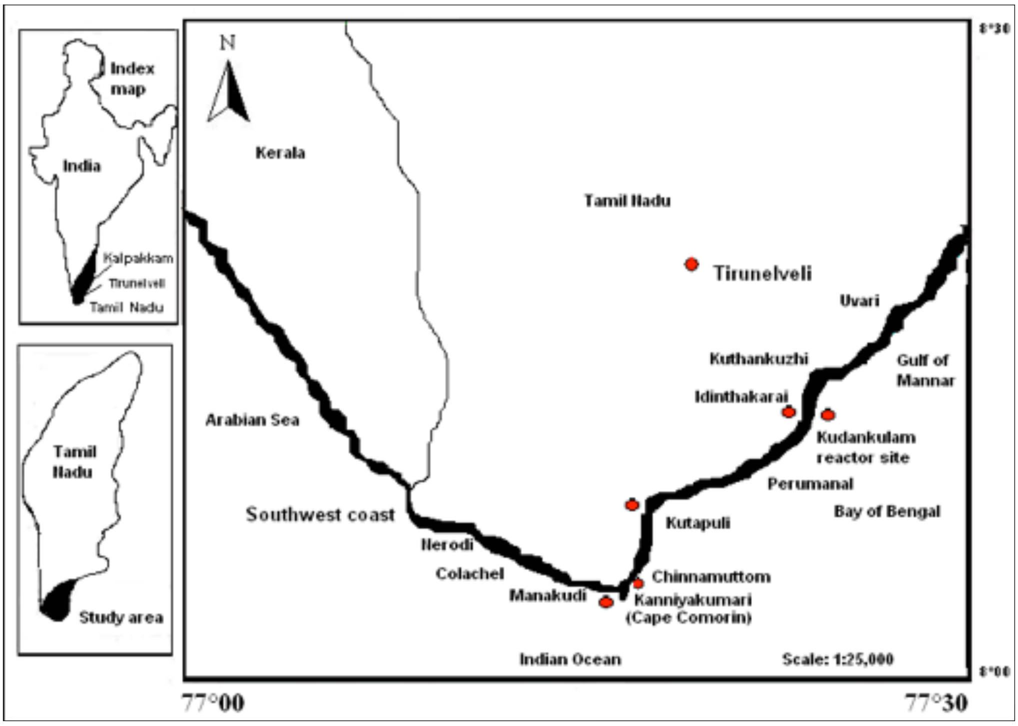


Figure 1 Map showing the study area

spontaneously deposited on both sides of a silver disc. The disc are counted with an alpha-ray counter (RC 605A, Nucleonix; efficiency of 35% for a $^{241}$Am standard; minimum detectable limit is 0.02 Bq). The average $^{210}$Po recovery was found to be 89%. The normal distribution of the data set was done using Lilliefors test (n≥50) and potential outliers, if any, were found using Walsh's test (n>60).These tests were performed using ProUCL v 4.1.

Polonium-210 concentrations in seawater of the study area ranged from 1.0 to 2.2 mBq l$^{-1}$. Overall, the concentration of $^{0}$Po in the fish muscle tissue of yellow fin tuna ranged from 32.9 ± 2.2 to 46.5 ± 3.6 Bq kg$^{-1}$. The raw data followed normal distribution at 95% confidence level and there were no potential outliers. Lesser activity of $^{210}$Po in fish muscle tissue is important to humans, who consume mostly this part. On comparison with world data on the preferential accumulation of $^{210}$Po by fishes, there stands a difficulty in attributing a broad variation on the feeding habits. Certain authors had found a wide range of variation of $^{210}$Po in fishes of Marshall Islands and had not explained the reason for this variation. Fishes living in the regions of equator have reported to contain more $^{210}$Po activity concentrations than in different species from colder, northern European waters, which is concordant with the present investigation. The $^{210}$Po activity for fishes was comparable with global average value of 2.4 Bq kg$^{-1}$ and global range of 0.27–27 Bq kg$^{-1}$.

The $^{210}$Po daily intake of each muscle tissue of fish varied between 0.4 and 0.9 Bq y$^{-1}$ (Table 2). The estimated dose due to $^{210}$Po intake ranged from 55.7 to 96.8 μSv y$^{-1}$. The dose calculated was comparable with values reported from Kalpakkam, Gulf of Mannar and from Ennore Creek, South India. The results obtained in this investigation was low compared to other regions, The study data plays a very important role in providing the data for the Nuclear Power plant commissioned at Kudankulam.

Table 1 Polonium activity and dose parameters

| **Site** | **$^{210}$Po activity (Bq Kg$^{-1}$)** | **Intake (Bq)** | | **CED (μSv)** | |
|---|---|---|---|---|---|
| | | Daily (d) | Annual (yr) | Daily | Annual |
| Idinthakarai | 92.5 | 0.93 | 337.6 | 0.39 | 141.8 |
| Uvari | 72.3 | 0.72 | 263.9 | 0.30 | 110.8 |
| Parangipettai | 48.5 | 0.49 | 177.0 | 0.20 | 74.3 |

Theme 5

# Marine biotechnology and bio-marine products

(disease detection, surveillance and control)

mbai-mecos 3

# New paradigms in invertebrate immunity with special reference to crustaceans

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Farming of crustaceans, dominated by shrimps, represents one of the most economically important sectors of the rapidly growing aquaculture food industry. Among the crustaceans, penaeid shrimp production constitutes ~62% of the total crustacean production (FAO, 2018). However, infectious agents and unfavourable culture conditions can have adverse effect on the immune system of shrimp making them susceptible to diseases. In this background, crustacean immunology, with emphasis on shrimps, is an important component in formulating strategies for the control of diseases in crustacean aquaculture. Two types of immune mechanisms have traditionally been accepted, innate and adaptive. Crustaceans depend on innate defense system for evading pathogens as they have no adaptive memory; in other words, they do not have the ability of producing immunoglobulins. Adaptive immunity in lower vertebrates reaches its maximum in mammals in which high recognition specificity is achieved due to the high variability in the molecular structures which can recognise specific epitopes. This is considered as a major advantage for the vertebrates to survive the infection. This is the reason adaptive immunity is often considered as the penultimate immune capacities. Further, innate immunity is sometimes considered "primitive" or "crude" compared to adaptive immunity. However, successful survival of invertebrates for millions of years, despite the lack of the 'advantage' of adaptive immunity, contradicts the belief. Further, it has been proved that from an evolutionary perspective, innate immune system has been evolved for a longer period of time than the adaptive immune system. Innate immune system has not only been efficient enough to recognize and respond to pathogens in invertebrates but the innate immune response has also been preserved in vertebrates. It is argued that this retention not only helps in resisting the infection before the elicitation of adaptive immunity, but also induce the signals that in turn alert the adaptive system of the presence of pathogens.

Although shrimp do not possess a vertebrate-like adaptive immune system, an efficient non-specific immune system provides protection against invading pathogens. Innate immune system operates through germline-encoded receptors which recognize invariant molecular constituents that are essential for the survival of the infectious agents. The molecular structures are not subject to variability, as any change or mutation affecting the structures will be lethal to the organisms. Since the molecular structures are conserved, these will be shared by many pathogens. These shared signatures of pathogens are called as Pathogen Associated Molecular Patterns (PAMPs) and the receptors in the hosts recognizing these patterns are known as Pathogen Recognition Receptors (PRRs). These innate immune responses comprise both cellular and humoral components and are regulated through several signal transduction pathways. RNAi mediated post-transcriptional gene silencing and microRNA regulation of immune response have also been found to be functional in shrimp. Further, some form of immune memory, termed "immune priming" and 'quasi immune response' is recorded in shrimp and these abilities have been exploited in verifying the immunoporotection against different pathogens. Besides, many adaptive immune molecules/pathways such as Down syndrome cell adhesion molecule (DSCAM), belonging to the immunoglobulin super family (IgSF), *Fibrinogen related proteins (FREPs),* vascular endothelial growth factor (VEGF) signaling pathway, interferon system-like antiviral mechanisms etc. have been reported from crustaceans.

In short, during the past few decades, there has been significant advancements in the field of crustacean immunology in the way of identifying novel defense molecules, reactions and effector pathways. Therefore, it is essential to not look into the innate immune mechanisms in invertebrates, especially crustaceans, from vertebrates' immune system/ function perspective. Although mechanistic explanation is lacking in proving the adaptive immune capability in many invertebrates, there are several phenomenological observations recorded in this direction. In this background, for effective prophylactic measures in controlling the diseases in crustacean aquaculture, it is essential to have deeper understanding about the complex immune pathways and responses in crustaceans.

# Marine natural products as novel molecular scaffolds for pharmaceutical applications

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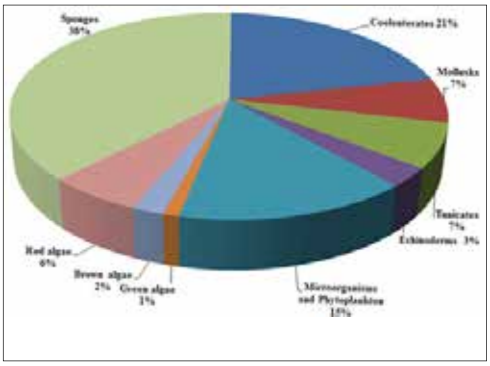
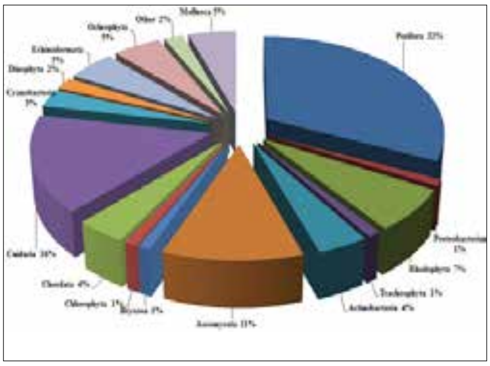
The marine environment covers a wide thermal range (from the below freezing temperatures in Antarctic waters to about 350°C in deep hydrothermal vents), pressure range (1-1000 atm), nutrient range (oligotrophic to eutrophic) and it has extensive photic and non-photic zones. This extensive variability has facilitated speciation at all phylogenetic levels, from unicellular microorganisms to mammals. Considering its great taxonomic diversity, investigations related to the search of newer bioactive compounds from the marine environment can be seen as an almost unlimited field. Of note is that the chemical compounds with pluralities of bioactive properties are present in the marine organisms as an adaptive mechanism to survive against the extreme stress factors in the oceanic ecosystems, which cannot be found in terrestrial organisms. The rich diversity of marine organisms represents an untapped reservoir of bioactive compounds with valuable pharmaceutical and biomedical use, and there is considerable potential for the exploitation of these compounds as functional food ingredients. Marine derived bioactive components and the functional food ingredients with potential health benefits demonstrated to possess advantageous as functional food with added health benefits.

Bio-prospecting of previously undescribed natural products mainly from the marine environment has been improved considerably over the previous few decades, resulting into an investigation of newer secondary metabolites (Blunt *et al.*, 2015; Blunt *et al.*, 2016; Faulkner 2000). It has been stated that the marine organisms were the most prominent sources of natural products, and therefore, have been favourite choices of natural product chemists (Blunt *et al.*, 2013; Blunt *et al.*, 2014; Faulkner 1999). Newer natural compounds of marine origin have delivered promising bioactive compounds with previously undescribed structures/skeletons, and these could be used as promising nutraceuticals and therapeutic agents against various ailments (Lordan *et al.*, 2011). Large numbers of newer natural compounds have been reported for their bioactivities, and as candidate molecules for potential drugs, even though, only a few of them qualified as drug candidates. Nonetheless, the worldwide and widespread bio-prospecting attempts have



not been stopped, and continuous search for chemically and structurally different secondary metabolites were increased. During the past few years, various bio-potential components have been isolated, identified and characterized from different marine organisms, such as molluscs, bryozoans, sponges, tunicates, corals, algae, microorganisms, echinoderms, cnidarians etc. The marine natural products have been acknowledged as highly desirable chemodiversity to support drug discovery and pharmacological applications by their diverse chemical features and the wide range of biological activities. According to the latest review 1378 new compounds were isolated from marine organisms in 2014 compared with 332 in 1984 (Blunt *et al*., 2012, 2013, 2014, 2015, 2016). Over 5 million species of the world in about 30 different phyla reside in the oceans. Because of the diversities of marine organism and habitats, marine natural products enfold a wide variety of chemical classes, including terpenes, shikimates, polyketides, acetogenins, peptides, and alkaloids of varying structures. A good number of natural products of interest to the pharmaceutical industry are secondary metabolites and several such compounds, derived from marine organisms, have been in clinical trials as experimental drugs. Over the past 50 years, numerous novel compounds have been isolated from marine flora and fauna having biological activities such as antibacterial, antiviral, antitumor, antiparasitic, anticoagulants, antimicrobial, anti-inflammatory and cardiovascular compounds.

Distribution of marine natural products by phylum and distribution of marine organisms among phylum were collected for natural product isolations over the period from 1971 to 2015 (Blunt *et al*., 2016)

Marine habitats harbour more than 2,00,000 identified invertebrates and algae species, although, a greater number of species were yet to be identified. It is significant that the marine ecosystem is an untapped reservoir of novel components with therapeutic potentials, and therefore, has been a key attraction of natural product chemists due to its comparatively unexplored biodiversity than the terrestrial systems. Reviews on various marine organisms, including bio-prospecting of molluscs, bryozoans, sponges, tunicates, corals, algae, microorganisms, echinoderms, cnidarians etc. were common and the classification of marine natural products among various phyla was given below. The distribution of various marine organisms evaluated for chemical investigations and natural product isolations over the period from 1971 to 2015 among different phyla was plotted below (Blunt *et al*., 2016). The compounds include alkaloids, peptides, terpenoids or steroids which provide natural immunities to the organisms. Likewise, the marine ecosystem encompasses a wide array of organisms with unique bio-potentials and bioactive metabolites. It is appropriate to state that marine natural products have had an important impact on chemistry, pharmaceutical and drug development areas over past few years, and found to be valuable sources for newer bioactive templates in upcoming years. The marine flora and fauna remain largely unexplored. Approximately 71% of the molecular entities listed in the Dictionary of Marine Natural Products have novel molecular structures compared to ~40% of those in the Dictionary of Natural Products. In NCI preclinical cytotoxicity screen, marine organisms show higher incidence of anti-tumor potential: 1% vs. 0.1% for terrestrial organisms. Number of new marine compounds reported each year is increasing >1000 compounds.

Various functional food formulations, pharmaceutical and biomedical products from marine flora and fauna including the fishery by-products provide a myriad of benefits for human health and multiple life threatening diseases, and therefore, are the attractive options for the food and pharmaceutical industry. The rich diversity of marine organisms represents an untapped reservoir of bioactive compounds with valuable pharmaceutical and biomedical use. The pioneering research work at ICAR-Central Marine Fisheries Research Institute envisages a systematic approach involving chemical profiling of major species of marine organisms for bioactive compounds with potential biological activities against different disease. The research works at ICAR-Central Marine Fisheries Research Institute developed a hitherto unraveled database of marine organisms with small molecular weight bioactive molecules responsible to combat various life-threatening diseases. This prestigious marine fisheries research institute of Indian Council of Agricultural Research (ICAR) has developed and commercialized the nutraceutical products Cadalmin™ Green Algal extract (Cadalmin™ GAe) and Antidiabetic extract (Cadalmin™ ADe) as green alternatives to synthetic drugs to combat rheumatic arthritic pain and type-II diabetes, respectively. The anti-inflammatory nutraceutical Cadalmin™ Green Mussel extract (Cadalmin™ GMe) from Asian green mussel *Perna viridis* has been commercialized. The active principles in Cadalmin™ GMe isolated from *P. viridis* exhibited potential capacities to inhibit experimentally induced inflammation, and can act as dual inhibitors of membrane arachidonate oxygenation by cyclooxygenase-2 and lipoxygenase pathways, thus decreasing pro-inflammatory prostaglandin/leukotriene synthesis and down-regulated the inflammatory sequence. The research works developed Cadalmin™ Antihypercholesterolemic extract, and Cadalmin™ Antihypothyroidism extract from seaweeds to combat dyslipidemia, and hypothyroidism, respectively, and the products were out-licensed to leading wellness/pharmaceutical Company. Cadalmin™ Antihypertensive extract for use against hypertension is being out-licensed. The commercialization of these products is significant to the coastal fishermen as this will enhance the demand to produce more green mussels and seaweeds along the Indian coastline.

# Tackling diseases in farmed aquatic animals

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Aquaculture is a highly dynamic sector contributing almost 50% of the global fish production (FAO, 2018). The Indian aquaculture sector is no different, led by shrimp and carp farming it has recorded an impressive growth during the past decades. Aquaculture is expected to play a significant role in contributing to food security, poverty alleviation and economic development of the poor in the coming years also. However, a closer look reveals that all is not well, and the sector is plagued by several issues, the most important being diseases. The metamorphosis from extensive to semi-intensive, intensive and super-intensive systems has significantly altered the pattern of occurrence and dispersion of diseases in aquaculture. High stocking densities, sub-optimal conditions, stress and ease of transmission have enhanced the susceptibility of cultured populations to diseases and making it the most important limiting factor for aquaculture. In addition to direct mortalities and production losses, impacts of diseases are manifested in other cross sections of the society, right from the marginal farmers to large-scale aquaculture business houses in the form of threatened livelihoods, unemployment, increased vulnerability and dwindling investor confidence.

Most of the serious diseases in aquaculture are infectious in nature, spreading fast and reaching epizootic proportions. Transboundary Aquatic Animal Diseases (TAADs) like Epizootic Ulcerative Syndrome, White Spot Syndrome Virus, Koi Herpes Virus and recently Tilapia Lake Virus are testimonies before us. Though non-infectious diseases also exist, their impact on production is generally less. Numerous external factors contribute to the occurrence and spread of diseases, like globalisation of trade in live aquatic animals and products; introduction of new species; movement/translocation of broodstock, postlarvae, fry and fingerlings; free/unregulated expansion of ornamental fish trade; interactions/mixing between cultured and wild populations; pollution and related anthropogenic activities leading to stress and reduced resistance; climate change; ineffective biosecurity measures and lack of awareness. Once a pathogen gets established in an aquatic environment, controlling and eradicating it is difficult. Climatic changes manifested by increasing atmospheric and ocean temperatures and associated extreme climatic events in the recent years have a direct bearing on diseases in aquaculture. Altered temperature, hydrological cycle and rainfall patterns, pH, salinity and DO levels, blooms, productivity, species growth and distribution etc. can affect aquaculture (FAO, 2018). This may result in the altered prevalence and/or virulence of pathogens, host susceptibility, transmission and distribution patterns, risk of escapes and emergence of new diseases.

The magnitude of losses coupled with socio-economic impacts makes disease control a priority. Approaches for controlling diseases vary widely depending on the location, type of farm, stage of fish cultured, etiological agents, environmental parameters, climatic conditions etc. The first step in any disease control programme is the diagnosis, which is usually done based on clinical symptoms and/or a battery of diagnostic tests, followed by suitable treatment/management. Chemotherapy is generally used for controlling diseases having an infectious etiology. However, many chemicals, both approved and unapproved are also used widely as prophylactics and growth promoters in aquaculture. Chemotherapy has its own limitations–are specific for particular pathogens and are not suitable for large farms areas or open water bodies. Compared to terrestrial farming systems, delivery/administration of the correct dose is very difficult, especially for stressed animals and leaching of drugs from medicated feeds may again reduce its bioavailability. Drugs may also affect sympatric wild populations or other non-targeted organisms in open waters and many of them leave their metabolites and residues in the environment paving way for antimicrobial resistance, thereby creating more problems than solutions. Use of unapproved antibiotics/ chemicals has already earned aquaculture a bad name. A good example is the 'sea lice' which has been considered as one of the most damaging pathogens in aquaculture. Rampant use of chemotherapeutants has made them resistant to most of the available compound classes including pyrethroids, organophosphates, avermectins and even against hydrogen peroxide. Many countries are adopting strict measures against residues in imports leading to rejection of consignments or ban on imports, affecting trade relations between countries. During the past few years there has been a reduction in usage of chemicals in aquaculture world over. Strict government regulations on drug/chemical usage, market pressures like rejection or reduction in prices for consignments with residues or those originating from regions where chemicals are used and awareness on the negative aspects have started reducing the usage of chemicals in aquaculture.

This has led to the exploration of several alternate approaches for disease management in aquaculture systems. Good management practices involving the usage of improved husbandry practices like optimum culture conditions, pathogen free seed, disease resistant stocks, dietary supplements including probiotics, prebiotics and immunostimulants, vaccination, pathogen monitoring and judicious use of chemicals can be implemented at farm levels. Dramatic control of many serious diseases has been achieved through a combination of chemotherapy, probiotics, vaccination and improved husbandry practices. The reduced efficacy of many drugs/chemicals against sea lice has paved way for novel, non-medical treatments including use of cleaner fish, lasers, snorkel barriers' and other high-tech solutions like hydrolicer and thermolicer which appears promising. Understanding pathogen (s) is very important, as the disease condition what we see is a complex situation resulting from the interaction/modification of the primary disease condition by various abiotic and biotic factors. The proverb "an ounce of prevention is worth a pound of cure" is true in the context of aquaculture health, because treating diseases is not an economically viable option. Prevention/ control of diseases can be achieved only through a holistic, proactive approach where better management practices hold the key. Such an approach considering other diverse elements of the microbiome that promote disease occurrence is gaining acceptance. A shift from a 'single-pathogen etiology' concept to 'pathobiome' concept will reveal a wider target for applying management strategies. From the prophylactic point of view, bolstering host resistance against pathogens is very important. Providing optimum culture conditions will help the animals to reduce the stress levels which indirectly reduce immunity and pave way for pathogen entry. Quality feed, and use of prebiotics, probiotics and immunostimulants will also help to enhance the natural resistance to pathogens. Probiotics are nonpathogenic bacterial strains which can be used to prevent diseases and promote growth while immunostimulants are known to stimulate the innate immune system of fish/ shrimp. Vaccination can bring about drastic changes in the fight against bacterial and viral diseases in fish. Technology to immunize large stocks simultaneously and development of multivalent vaccines have enhanced the scope of vaccination in aquaculture. Presently commercial vaccines are available against 25 diseases in fish and most of them are killed/ attenuated, adjuvant based oral or injectable vaccines. Rapid advances have resulted in the development of vaccines based on DNA, synthetic peptides, recombinant vectors, genetically modified and subunit vaccines. Coupled with good management practices, vaccine technology offers great potential in controlling diseases in aquaculture.

Timely intervention plays an important role in the management of diseases. The time span from the first report of disease/mortalities in the field, its diagnosis, establishing the etiological agent and finally the treatment/ management leading to the elimination of the pathogen is critical as it determines the quantum of production losses in the system. Any management action to prevent the introduction and spread of disease-causing agents in aquaculture facilities can be termed biosecurity. Biosecurity essentially revolves around the identification of risks and hazards and their mitigation/management. FAO (2007) has identified seven risk sectors in aquaculture which included pathogen, food safety, genetic, environmental, ecological, social and economic risks. Risk analysis basically depends on scientific/technical information/knowledge and application of sound epidemiological principles to improve biosecurity assessments, surveillance, diagnostics, early warning, emergency preparedness, response and contingency planning. Generally at farm level, practices like strict quarantine measures, sanitation of equipment, proper water treatments, pathogen free seed, clean feed, proper disposal of dead animals etc. increases the biosecurity levels and minimize pathogen entry/spread. Meticulous application of biosecurity measures can prevent most disease outbreaks in aquaculture. Recently FAO (2018) suggested a new concept to address aquatic disease problems – Aquaculture Biosecurity Progressive Management Pathway (PMP) which envisages a step-wise, risk-based management approach which has four stages. The first step involves identifying/defining the aquaculture risks and developing a long-term, national aquaculture biosecurity strategic plan; the second step deals with the implementation of the plan, followed by continuous monitoring and evaluation to strengthen its implementation; in the third step development of sector-specific and disease-specific risk management plans including zoning and restrictions and constant surveillance for existing/emerging disease threats are executed for establishing freedom/defending health status and in the fourth step a 'Sustainable and Resilient National Aquaculture System' is established. Since this approach promotes active stakeholder engagement and collaboration, public-private sector partnership (PPP) is imperative for its successful implementation. Epidemiology is an emerging field as far as aquaculture is considered and epidemiological tools are widely used in containing aquatic animal disease outbreaks and aquatic health management. Models based on epidemiological data can also be used to assess the risks as well as to predict the onset of disease outbreaks; however this may require quality data inputs. Aquaculture information management is another component where communication channels are always open between farmers, scientists and government officials. Exchange of information will increase the level of preparedness and enhance responses thereby preventing the spread of diseases and reduce the vulnerability of the industry.

Governments also play a major role in providing a conducible environment for aquaculture. Capacity strengthening of farmers and technical personnel in handling diseases, diagnosis, responses etc. is very important. Framing rules and regulations related to licensing of farms, zoning and compartmentalization, enforcing fallow periods and synchronized stocking policies, disease monitoring and surveillance programmes, code of conduct for sustainable aquaculture, hazard analysis and critical control points, compliance with good aquaculture practices, certification etc. and their enforcement are a must. Each country should have a strategy and action plan on handling unexpected disease outbreaks. Regional and international intergovernmental organizations can coordinate the efforts by governments especially when dealing with TAADs.

Thus, tackling diseases in aquaculture is a shared responsibility, government agencies, local bodies, intergovernmental organizations, academic and R&D institutions, private industries, farmers and civil society organizations can all contribute for a productive aquaculture that is environmentally neutral and resilient in the long term.

# Histopathological manifestations in Asian seabass, *Lates calcarifer* (Bloch, 1790) experimentally infected with *Vibrio alginolyticus*

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Highly virulent *Vibrio alginolyticus* has been the cause of vibriosis in Asian seabass reared in open sea floating cages. There are not many reports on the pathological manifestations of experimental *V. alginolyticus* infection in Asian seabass. The aim of the present investigation was to describe the chronology of histological lesions in different organs of Asian seabass following intra-peritoneal (IP) injection challenge with a virulent strain of *V. alginolyticus*. Apparently healthy Asian seabass juveniles (mean weight: 15 ± 3 g) were divided into 3 groups of 27 fishes. The first two groups were intra-peritoneally inoculated with bacterial suspension of *V. alginolyticus* at a dose of 0.2 ml ($10^4$ CFU/ml) per fish and the third group of fishes kept as experimental control was injected with 0.2ml of PBS. Post challenge samples of liver, kidney, spleen and gill were collected at 0, 2, 4, 6, 8, 10, 12, 24, and 48 h for histo-pathological and microbial evaluation.

Mortality in challenge group was significantly higher than that of control group, and most of the mortalities occurred within 24-48 hour post challenge (hpc). Bacterial isolation on TCBS from diseased fishes at various time intervals gave morphologically similar bacterial isolates, indicating a common bacterial aetiology. Molecular identification of the bacterial isolates was carried out by 16S rDNA sequencing and the isolate was confirmed as *V. alginolyticus*.

There were no significant histopathological changes in any of the evaluated organs up to 10 hpc. The splenic tissue of control Asian seabass revealed normal red pulp structure with compacted ellipsoids and few melano-macrophage centres (MMC). In experimentally challenged Asian seabass, at 12 hpc, approximately 95–100% of spleen showed increase in red pulp and accumulation of erythrocytes in white pulp, increased MMC and hemosiderin. At 24 hpc, moderate splenitis with loosening of tissue structure and haemorrhage in splenic parenchyma in addition to hemosiderosis were evident. At 48 hpc, acute changes with diffuse fibrinoid necrosis of ellipsoidal sheath and aggregation of inflammatory cells were observed.

Kidneys of the control group exhibited normal organization of kidney tubules. In experimentally challenged Asian seabass, at 12 hpc, approximately 75% of kidney tissue showed haemorrhage, infiltration with inflammatory cells, interstitial nephritis and tubular degeneration with hemosiderin deposits. At 24 hpc, diffuse necrosis of renal tubules, increased number of hemosiderin deposits, loosening of tissue structure and severe haemorrhage was observed. At 48 hpc, severe interstitial nephritis with extensive haemorrhage, increased MMC and hemosiderin deposits, extensive congestion and haemorrhage were also observed.

Hepatic parenchyma of the control group revealed normal polygonal hepatocytes with normal blood vessels with mild congestion and occasional fatty change. In experimentally challenged Asian seabass, at 12 hpc liver showed moderate congestion, moderate haemorrhage and extensive blood accumulation in hepatic sinusoids. At 24 hpc, the liver showed pyknosis, severe haemorrhage and severe congestion. After 48 hpc, hydropic degeneration of hepatic cells, cellular swelling, hepatic congestion with extremely dilated sinusoidal space, and haemorrhage in the hepatic parenchyma were observed.

In gills, normal primary and secondary lamellae were seen in the control group. During the first 2–12 hpc, no lesions were observed in any of the examined Asian seabass. From 12 to 48 hpc, few sloughed epithelial cells of secondary lamellae were seen in the majority of gills examined.

These observations demonstrated that *V. alginolyticus* rapidly gained entry into fish organs and caused histopathological changes in spleen, kidney and liver following the IP challenge. The lesions observed in this study are in conformity with the findings seen in natural *V. alginolyticus* infections in other fish species including cobia (*Rachycentron canadum)*, Gilt-Head Sea Bream (*Sparus aurata* L.) and sea horse (*Hippocampus reidi* Ginsburg, 1933).

In the current study, no conspicuous external lesions or clinical signs were observed which could be due to the acuteness of infection. The lesions were predominantly haemorrhagic in nature and were present in all the vital organs. Most species of vibrios cause fatal haemorrhagic septecemia. The release of extracellular products with haemolytic activity by the organisms is responsible for extensive haemorrhage. In infections caused by vibrios, hemolysins are the major virulent factors responsible for haemorrhagic septicaemia, which is the most significant feature of vibriosis.

# Chromenyl derivatives from seafood *Sepiella inermis*: Newly described natural leads possessing antioxidant, anti-inflammatory and antidiabetic activities

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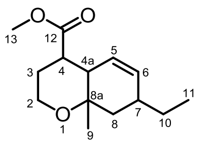
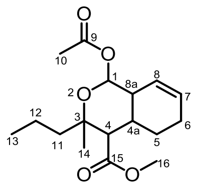
Landing and consumption of cephalopods have increased in the last few decades due to their prominent nutritive values and various biological activities. These pharmacological activities may be attributed to the presence of different bioactive compounds in the species. Chromenyl compounds and their chemotypeisochromenyls were referred to a significant category of natural or synthetic based small molecular weight bio-actives

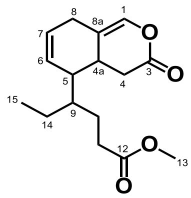


Methyl 7-ethyl-hexahydro-8amethyl-2H-chromene-4-carboxylate (**1**)

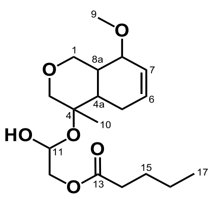


Methyl 1-acetoxy-hexahydro-3-methyl-3-propyl-1H-isochromene-4-carboxylate (**2**)

**Spineless cuttlefish**
***Sepiella inermis***



Methyl 9□(4,4a,5,8□tetrahydro□3□oxo□3Hisochromen□5□yl)hexanoate (**4**)



11□(3,4,4a,5,8,8a□Hexahydro□8□methoxy□4□methyl□1H□isochromen□4□yloxy)□11□hydroxyethyl pentanoate (**3**) with structural functionalities and reported for various pharmacological potencies. Among cephalopods, spineless marine cuttlefish *Sepiella inermis* encompasses a major share in the marine fisheries sector and has been considered as a popular dietary species in Asian and Mediterranean coasts.

Bioassay-directed purification of organic extract of *S. inermis* ensued in the characterization of four chromenyl derivatives namely methyl 7-ethyl-hexahydro-8amethyl-2H-chromene-4-carboxylate (1), methyl 1-acetoxy-hexahydro-3-methyl-3-propyl-1H-isochromene-4-carboxylate (2), 11-(3,4,4a,5,8,8a-Hexahydro-8-methoxy-4-methyl-1H-isochromen-4-yloxy)-11-hydroxyethyl pentanoate (3) and Methyl 9-(4,4a,5,8-tetrahydro-3-oxo-3Hisochromen-5-yl)hexanoate (4). Theisolated metabolites were checked for their free radical scavenging,anti-inflammatory and anti-diabetic potentials by selective *in vitro* models. The studied compounds exhibited significantly greater antioxidant potencies (IC50 ≤ 0.57mg $mL^{-1}$) when compared with $\alpha$-tocopherol. Among the metabolites chromenyl derivative (2) displayed pro-inflammatory cyclooxygenase-2 (COX-2) (IC50 0.75 mg $mL^{-1}$) and 5-lipoxygenase (5-LOX) (IC50 0.77mg $mL^{-1}$) inhibitory activities. The titled compounds displayed the selectivity indices (IC50anti-COX-1/IC50 anti-COX-2) greater than 1.16, in comparison with synthetic anti-inflammatory drug ibuprofen (0.44), which attributed to their greater selectivity towards inducible pro-inflammatory enzyme COX-2. The substituted 1*H*isochromenyloxy-11-hydroxyethyl pentanoate isoform (3) efficiently inhibited the carbolytic enzymes along with key regulator of insulin secretion dipeptidylpeptidase-IV (IC50 0.16 mg $mL^{-1}$). The molecular docking simulations displayed optimum binding affinity of the compound 3 (−10.01 $kcalmol^{-1}$) with dipeptidyl peptidase-IV and lesser inhibition constant (K*i* 46.41 nM), hexahydro isochromenyl isoform (2) (−5.21 $kcalmol^{-1}$) with 5-LOX and lower inhibition constant (K*i*1.07μM) compared with other metabolites. The permissible hydrophobic-hydrophilic balance (log Pow ~ 2) of the compounds appeared to play significant roles in its greater anti-hyperglycemic and anti-inflammatory activities. Owing to the pharmacological activities of the metabolites the *S. inermis* could be utilized as functional food ingredients to combat oxidative stress, hyperglycaemia, and inflammation-related risks.

# Jellysafe–First aid package for jellyfish sting management

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Jellysafe is a first aid package developed for the sting management of Jellyfish. This package contains a pair of gloves, Vinegar 200ml, Jellycard, Caladril Lotion, Forceps, User guide and Jellyfish information Pamphlet. Jellyfish diversity of India can be grouped under six categories based on their stinging capacity viz., life-threatening, extremely stingy, quite stingy, moderately stingy, mildly stingy and does not sting. This technology package has been developed to alleviate the pain caused by the commonly occurring jellyfishes along the Indian coast which fall in the category from extremely stingy to mildly stingy *viz.*, *Chrysaora* sp., *Rhopilema* sp., *Lobonemoides* sp., *Cyanea* sp., *Acromitus* sp., *Lychnorhiza* sp., *Cephea* sp. *Thysanostoma* sp., *Pelagia noctiluca*., *etc.* This "jellysafe" protocol advises following;

- Carefully scrape the stinging cells out of your skin using the plastic card given.
- If tentacles of jellyfish are stuck on your skin, use forceps to remove them.
- Rinse with vinegar, on the affected site for 30 seconds.
- Apply Calamine lotion or Lidocaine to help relieve itching and discomfort.

If pain is not manageable and continues for more than 30 minutes, or you start to have difficulty in breathing consult nearby hospital for treatment.

Vinegar which contains 3-5% acetic acid; need to be poured on the affected area for 30 seconds, which inactivates the nematocyst of jellyfish there by reducing the venom injection into the skin. After vinegar application, to help relieve itching and discomfort Calamine or Lidocaine can be used. This package advises not to use freshwater to rinse the affected area which further activates the nematocysts of jellyfish. Similarly avoid using ice cubes. Box jellyfish stings are highly painful hence; they have to be treated at the hospital. This package of practice to manage jellyfish sting management is best suited for fishermen and recreational bathers in the sea during swarming in summer months along the Indian coast.

# Molecular epidemiology of *Aphanomyces invadans* involved in epizootic ulcerative syndrome outbreaks across different countries

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Epizootic ulcerative syndrome (EUS) is an epizootic ailment implicated in mass mortalities of many cultured and wild, freshwater as well as estuarine fishes of several countries. Recognizing its potential impact on fisheries sectors, Office International des Epizooties (OIE) has listed EUS as a reportable disease. *Aphanomyces invadans*, the primary etiology of EUS has spread among 24 countries within 4 continents since its first outbreak in Japan during 1971. Interestingly, as not all isolates of *A. invadans* are fish pathogenic, it is possible that *A. invadans* is a heterogenous species with variants displaying different pathogenicity. Increasing global dissemination of *A. invadans* necessitate urgent interventions through novel and effective preventive and control strategies. Molecular epidemiological research targeting the transmission, geographical distribution, and relationships between strains of various outbreaks and pathogenicity could design novel control and preventive measures against many diseases; conversely molecular epidemiological studies of EUS pathogen has not been conducted. Internal transcribed spacer (ITS) region of ribosomal RNA operon is a well-recognized molecular epidemiological marker for many fungal and parasitic diseases and sequence variations within ITS regions (ITS1 and ITS2) have been extensively used in phylogenetic and epidemiological studies of many pathogens. Considering all these facts, the present study was conducted to measure the intraspecific divergence within the isolates of *A. invadans* from various countries based on ITS region. Further, applicability of ITS regions (Full ITS as well as ITS1 and ITS2 separately) in molecular epidemiology of EUS was evaluated. Initially, ITS regions of *A. invadans* involved during the EUS outbreak causing heavy mortality among estuarine fishes of Kerala, India during 2018 and another isolate involved in EUS outbreak from freshwater aquaculture farms of Kerala was amplified and sequenced. Subsequently, all the previously reported sequences of *A. invadans* isolates from EUS outbreaks of various countries and different *Aphanomyces* sp. were retrieved from NCBI database. Multiple sequence alignment of these sequences with corresponding sequences from our study were performed and the aligned data was used to compute divergence and percent identity values of each sequence pair, followed by phylogenetic analysis. Surprisingly, all the isolates showed high degree of genetic homogeneity in both ITS regions and were clustered together during phylogenetic analysis. When the molecular phylogenetic relationships between *A. invadans* with different *Aphanomyces* sp. was analyzed using ITS regions, three independent well resolved lineages, each containing plant parasitic, animal parasitic, and saprotrophic or opportunistic parasitic isolates were obtained, confirming that *A. invadans* is distinct from all other *Aphanomyces* species. However, within the species *A. invadans*, divergence was zero in both ITS1 (except FM 999230) and ITS2. Sequence identity was 95.5%-100% and 98.9-100% in ITS1 region and ITS2 respectively suggesting that that ITS2 is more conserved than ITS1. Altogether, the results showed that *A. invadans* represent a slowly evolving group regardless of causing EUS outbreaks in

fresh/estuarine environments and the same clone of fungus has spread all over the world over the period of 18 years. The low genetic diversity observed in the study emphasize the increased chances for further spread of the same pathogen throughout the world causing much more economic losses, necessitating strict surveillance and development of sound biosecurity measures against this highly destructive disease. At the same time, the study pointed out that sequence variation existed within the ITS regions is not sufficient to distinguish among different strains involved in EUS outbreaks, warranting future search focusing on additional genetic regions for subtyping and molecular epidemiological investigations of *A. invadans* isolates.

# Nacre incorporated carrageenan chitosan scaffold for dermal regeneration

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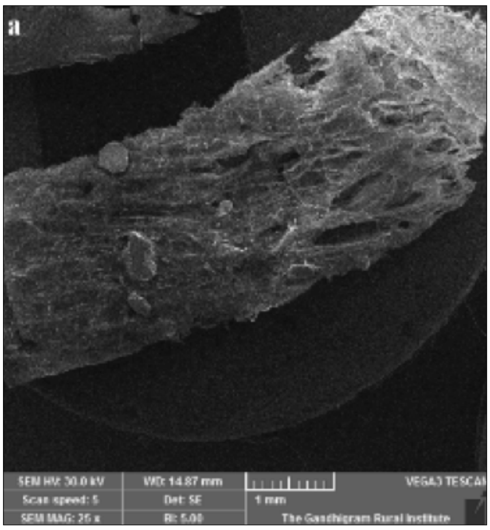
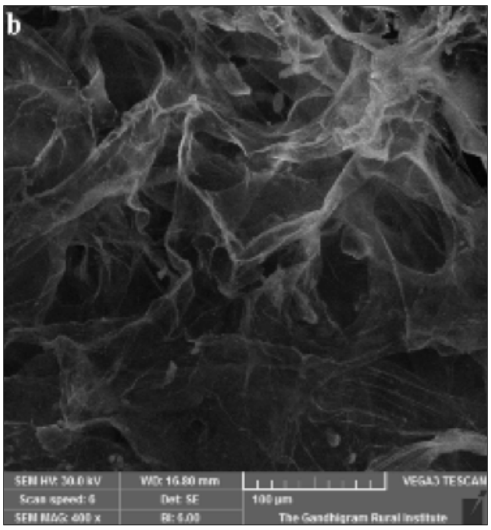
Dermal regeneration is the biological process of skin wound healing. However, the process of wound healing may be delayed when more layers of the skin are prone to damage. To enhance the healing process, wound dressings are applied to the damaged area. Such treatments are insufficient in serious burn victims with chronic wounds, and other wounds that encompass large areas of the body. Hence, there is a need for new skin replacement strategies. To restore the skin to its natural healthy conditions, the tissue replacement should closely resemble the skin layering and composition. Tissue Engineering is a field of science that relies extensively on the use of porous three-dimensional scaffolds to provide an appropriate environment for the regeneration of tissues and organs. These scaffolds act as a template for the tissue formation and the cells are typically seeded along with the growth factors. The scaffold seeded with cells, cultured *in-vitro* to synthesise tissues, can be implanted at the site of injury. The scaffolds can be fabricated using different biomaterials.

Nacre also known as the "mother of pearl" is a biomineralized material secreted by the mantle cells of molluscs. Nacre has been used as a potential component in bone regeneration and its Water-Soluble Matrix is also known to help in osteogenic regeneration. Nacre can be employed in the treatment of burn injuries as the nacre components are identified to have capabilities to recruit fibroblasts at the site of injury and increase the secretion of the collagen at the site of implant. Nacre act as a chemoattractant for fibroblast cells and enhances the normal process of wound healing. Carrageenan is a sulphated polysaccharide



a) Surface view of the carrageenan chitosan nacre scaffold under Scanning Electron Microscope



b) Magnified view of the carrageenan chitosan nacre scaffold under SEM that occurs in the red seaweed. Carrageenan is known to mimic the characteristics of the sulphated polysaccharides (chondroitin sulphate or dermatan sulphate) in the Native Extra Cellular Matrix which are essential for cell differentiation. Chitosan is a biocompatible material that can be used in a medical device to treat, augment or replace any tissue, organ, or function of the body. Chitosan can mimic the structural characteristics of the glycosaminoglycans and play the role of glycosaminoglycans *in-vivo*.

A scaffold fabricated using carrageenan, chitosan and nacre can act as an efficient substitute for skin regeneration. Hence, a scaffold using carrageenan chitosan nacre was fabricated by freeze drying method. The morphology of the scaffold was analysed by Scanning Electron Microscopy and the pore size was found to be 14-75 μm. The pyrolytic property was analysed using Thermogravimetric analysis. The stability of the scaffold was assessed by determining the zeta potential of the scaffold. The potential of the scaffold was -41 mV which shows that the scaffold is stable. The interaction of the polymers was determined by FTIR analysis which showed peaks around 1446.28 $cm^{-1}$ indicating the presence of carbonate group in the scaffold. The scaffold also showed optimal swelling ratio and absorbed up to 80% of the total protein in the provided medium. Degradation rate of the scaffold with nacre was also seen to be controlled. Biocompatibility of the scaffold was determined using human epithelial cell lines (A375 cells). The scaffold was seen to support proliferation of these cells and the viability of the cells within the scaffold was not less than 90%. Since the scaffold supported the growth of skin cells, it can be suggested as a promising candidate for application in skin regeneration.

# Complete mitochondrial genome of the Indian scad *Decapterus russelli*

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Mitochondria contain their own genome, a circular DNA molecule present in several copies per organelle. The mitochondrial (mt) genome is essential for life in almost all eukaryotes and repertoire of encoded genes is extremely conserved. Mitochondrial genes are popular genetic markers for evolutionary studies because they are effectively single copy, they show clonal pattern of inheritance and reduced effective population size. Generally, mtDNA is considered as a good molecular marker for phylogenetic analysis among fish taxa. However, the use of short mitochondrial gene fragments exhibit limitations in resolving complicated phylogenetic relationships in many fish lineages. The supplementary informative sites from longer DNA sequences (e.g., mitochondrial genomes) allow these deeper branches and higher level relationships to be more fully resolved.

An accurate phylogeny is essential for the complete understanding of vertebrate evolution. Therefore, questions of vertebrate relationships have been a primary focus in the field of molecular systematics. Fossils can provide evidence of morphological change, but the genetic changes associated with evolution can only be discerned from comparisons among extant taxa. Here arises the need for mitogenome characterization, by which one can delineate the relationship among extant taxa and thereby provide accurate results regarding evolutionary relationship at the genetic level. Genomic information is considered to be reliable for the efficient implementation of strategies to study evolutionary relationships, phylogeography and phylogeny.

Since Mitochondrial DNA (mtDNA) is an important model system in aquaculture research, the characterization of complete mitochondrial genome of fish species could contribute to the studies on its phylogenetics and provide strategies for fisheries management. The fishes of the family Carangidae are an important group of exploited pelagic resources of India. Carangids constitute the third most important resource, ranked next to the Indian oil sardine and Indian mackerel. The Indian scad, *Decapterus russelli* is one of the most exploited pelagic fish species in this family and is distributed on both east and west coasts of India. The complete mitogenome of this species was determined by overlapped Polymerase Chain Reaction. The circular mitochondrial DNA molecule is 16542 base pair (bp) in length which included a standard set of 13 protein coding genes, 22 transfer RNA genes (tRNA) genes, 2 ribosomal RNA genes (12S rRNA and 16S rRNA), and 2 non coding regions; control region and origin of light strand replication. Most of the genes were encoded on the heavy strand except ND6 gene and 8 tRNA genes (Ala, Asn, Cys, Gln, Glu, Pro, Ser (UCN) and Try), which were encoded on the light strand. The total length of the protein coding genes was 11425 bp accounting for 69% of the entire genome. The organization of the genome is similar to other typical vertebrate mitochondrial genomes. The overall base composition of the genome is 27.5% A, 30.2% C, 25.4% T and 16.9% G showing an obvious anti G bias observed in teleosts. These sequence data could provide useful information for further studies in fishery science such as studies on molecular phylogenetics and conservation genetics.

# Bioactive aryl-enclosed macrocyclic polyketide from macroalgae associated *Gamma proteobacterium shewanella* algae

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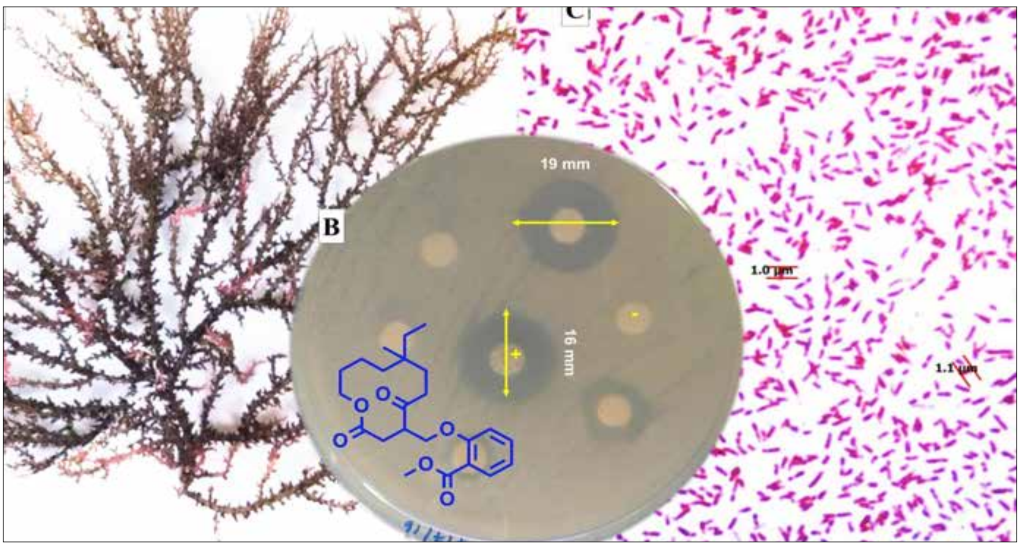
The emergence of antibiotic-resistant pathogens and the need for novel antimicrobial agents has demanded the investigation of new habitats to screen the production of bioactive substances. In recent times, macroalgae-associated bacteria have gained attention concerning their potentials to produce bioactive metabolites with biotechnological and pharmaceutical applications. Increasing reports of macroalgae-associated bacteria with potential bioactivities revealed their significance to isolate pharmacologically active microbial specialized metabolites (Kanagasabhapathy *et al*., 2008; Penesyan *et al*., 2009). Amongst different phyla of marine bacteria, *Firmicutes* and *Gamma-proteobacteria* were documented as vital sources of bioactive compounds with pharmacological significance. *Shewanella algae* and *Gamma proteobacteria* in general, particularly those with symbiotic associations with higher organisms, have been reported as an exclusive source of natural products with unique structural attributes of secondary metabolites including polyketides, non-ribosomal peptides and heterocyclic compounds with peculiar biosynthetic logic (Horta *et al*., 2014; Timmermans *et al*., 2017).

In this study, we have focused to isolate and characterize the bioactive secondary metabolites responsible for the antioxidant and antibacterial activities of the ethyl acetate (EtOAc) extract of macroalgae associated bacterium collected from the southeast coast of




The representative image of the host algae, *Hypnea valentiae* (A), zone of inhibition obtained with the aryl enclosed macrocyclic polyketide against methicillin resistant *Staphylococcus aureus* (B) Gram staining image of *S. algae* MTCC 12715 and (C) were shown. Structure of aryl enclosed macrocyclic polyketide isolated from heterotrophic *S. algae* MTCC 12715, is shown in inset.

India. The isolate was identified phenotypically and genotypically. Further, the DPPH (Chew *et al.*, 2008) and $ABTS^+$ (Wojdylo *et al.*, 2007) radical scavenging assays were performed to quantify the antioxidant potentials of studied compound and the antibacterial activity was assessed by broth dilution assay, according to the National Committee for Clinical Laboratory Standards (NCCLS 2004). The bioactive compound purified was identified with exhaustive spectroscopic identification methods, such as, Nuclear Magnetic Resonance (NMR) encompassing proton ($^1$H-NMR), carbon ($^{13}$C-NMR), $^{135}$DEPT (distortionless enhancement by polarisation transfer), $^1$H-$^1$H COSY (homonuclear correlation spectroscopy), HSQC (heteronuclear single-quantum correlation), HMBC (heteronuclear multiple bond correlation), and nuclear overhauser effect (NOE) spectroscopy experiments in conjugation with Fourier transform-infrared spectroscopy (FT-IR) and mass fragment analyses.

The bioactive bacterium isolated from *H. valentiae* was identified as *Shewanella algae* MTCC12715 with biochemical and 16s rRNA analysis. Bioassay guided fractionation and repetitive chromatographic purification methods resulted in previously unreported aryl-enclosed twelve-membered macrocyclic polyketide characterized as 2'-[(8-ethyl-8-methyl-2,5-dioxo-1-oxacyclododecanyl) methoxy]-methyl benzoate from the candidate bacterium. The titled macrocyclic polyketide displayed potential antibacterial activity against clinically relevant pathogenic strains, for instance, Methicillin Resistant *Staphylococcus aureus* and *Escherichia coli* with MIC 3.75 μg/mL, compared to the standard antibiotic chloramphenicol (MIC 6.25 μg/mL). Further, Potent antioxidant activity of the compound was characterized by its greater scavenging effects on 2,2-diphenyl-1-picrylhydrazyl radical and 2,2'-azino-bis-3-ethylbenzothiozoline-6-sulfonic acid (IC50 0.59 and 0.53 mg/mL, respectively) compared to standard, $\alpha$-tocopherol (IC50 > 0.65 mg/mL). These results indicate, the studied aryl-enclosed macrocyclic polyketide compound could be utilized as potent antioxidant and antibacterial agents in the medicinal preparations.

Theme-5 Marine biotechnology and bio-marine products
(disease detection, surveillance and control)

# Biodegradation of the Pyrethroid pesticide Cyflutrin by the halophilic bacterium *Photobacterium ganghwense* isolated from coral reef ecosystem

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Pesticides are widely used for preventing and controlling diseases and pests of agriculture crops. But the harm caused by pesticide residues have brought serious issues to both humans and the environment. This paper deals with the bacterial degradation of the pyrethroid pesticide Cyfluthrin by the halophilic bacterial strain, *Photobacterium ganghwense* isolated from coral reef ecosystem. Cyfluthrin pesticides are used widely in agriculture sector as an efficient pest control system owing to its broad spectrum activity, high efficiency and low mammalian toxicity. However, the widespread and continuous usage of Cyfluthrin has caused substantial pesticide residues in aquatic ecosystems, which have affected aquatic organisms as well as human health. Cyfluthrin has endocrine-disrupting, hepatotoxic, immunotoxic as well as cytotoxic properties and it adversely affects reproduction. Also it is difficult to be degraded in the natural conditions and an intermediate metabolite; 3-phenoxy benzoic acid would be produced during the degradation process, causing secondary pollution of agricultural products. Therefore, Cyfluthrin pesticides pose considerable threat to humans and other non-target organisms. Cyfluthrin has also been detected in water, sediment and various biological samples. Therefore, effective remediation of Cyfluthrin-polluted systems is desirable.

A halophilic bacterial strain T14 isolated from coral mucus *Acropora* sp. in the coral reef ecosystem off Tuticorin, Tamil Nadu was identified as *Photobacterium ganghwense*. The strain was characterized by biochemical and molecular methods. The strain was found to be catalase and oxidase-positive, motile, oval/rod-shaped cells. Molecular characterisation using 16S rRNA gene revealed >99% similarity to *P. ganghwense*. The strain has been reported to have high pyrethroid degradation ability. The present study attempted to assess the ability of strain T14 to degrade the pyrethroid pesticide Cyfluthrin. The bacterial strain was incubated with the pesticide Cyfluthrin (100 mg $l^{-1}$) prepared in the culture medium (along with control medium without bacterial inoculation) for 3 days under prescribed conditions and change in biomass was monitored daily. Post-treatment, the media were centrifuged to sediment the bacterial cells, the supernatants obtained were filtered using membrane filters (0.45 μm) and the filtrates were analyzed using GC/MS-MS technique to determine the difference in concentration of the pesticide in the control medium (containing 100 mg l-*1*) and bacterial treated medium, which in turn reflected the bio-degradative ability of the bacteria. Cytotoxicity of the filtrate was compared with that of the original pesticide suspension in the medium on a fish cell line EM4SpEx derived from *Epinephelus malabaricus*, which indicated reduction in cytotoxicity of the bacterial treated pesticide suspension. *The results of the present study clearly showed the pyrethroid degradation ability of P. ganghwense* strain T14.

# Pyocyanin as a novel aquaculture drug to control Vibriosis in Shrimp farms

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Shrimp aquaculture production alone contributed 6,90,001 tonnes to the total fish production of the country during the year 2017-18. Due to intensive farming practices, the occurrence of diseases has become quite common. Vibriosis is one such prevalent bacterial infection in shrimp farms caused by *Vibrio* spp. Vibrios belong to the natural microflora of aquatic systems but they are also opportunistic pathogens. Indiscriminate use of antibiotics in aquaculture has resulted in multi-antibiotic resistant *Vibrio* spp.

In this light, the requirement of newer drugs that are effective, yet less detrimental to the ecosystem has become significant. Pyocyanin (5-methyl-1-hydroxyphenazine), a blue coloured phenazine pigment produced by *Pseudomonas aeruginosa* has shown to possess anti-vibrio property. Five isolates of *P. aeruginosa* with antagonistic property have been deposited in the Microbial Culture Collection of Bacteria (MCCB) of the National Centre for Aquatic Animal Health (NCAAH), CUSAT, Kerala, India. Of these, MCCB 102 and 103 originated from brackishwater environment, MCCB 117 and 118 from marine, and MCCB 119 was from freshwater. Maximum production of pyocyanin was obtained when the isolates were grown in a salinity range of 5-10g/L. In the case of *V. harveyi,* pyocyanin was found to be bacteriostatic at 5mg/L and bactericidal at 10mg/L. In a pilot-scale study of recirculating aquaculture system reared with juveniles of *P. monodon*, pyocyanin could significantly bring down heterotrophic bacterial load of the system with specific reference to *Vibrio* spp.

Toxicity studies on human (L-132), insect (Sf9), finfish (RTG-2) and shrimp (PmL-Sf9 hybrid) cell lines showed that pyocyanin was non-toxic at the concentration required for its antagonistic activity. Toxicity tests conducted on brine shrimp, larval and juvenile stages of *P. monodon* also produced similar results. Strikingly, pyocyanin did not inhibit nitrification in recirculating aquaculture system when studied *in vitro* and *in vivo* employing specific nitrifying bacterial consortia. In addition to optimizing the culture conditions for enhanced production of pyocyanin by *P. aeruginosa* MCCB 102 and 103, a genetically modified PA-pUCP-Phz$^{++}$ strain of *P. aeruginosa* MCCB 117 could also be developed. In terms of production, as an economically feasible aquaculture drug, the yield of pyocyanin from the genetically modified strain was 45mg/L at a cost of around Rs. 3000. Shelf life of pure pyocyanin at -20$^{0}$C is two years. The results are suggestive of the potential and possibility of pyocyanin as a safe aquaculture drug for the control of vibriosis in shrimp aquaculture including recirculating aquaculture systems.

# Cloning, expression and characterization of L-Asparaginase contig from *Sardinella* gut microbiome

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L-asparaginase catalyses hydrolysis of l-asparagine to l-aspartic acid and ammonia. It is an anti-neoplastic agent used for the treatment of acute lymphoblastic leukemia, acute myelocytic leukemia, acute myelomonocytic leukemia, chronic lymphocytic leukemia, Hodgkin disease, lymphosarcoma, reticulosarcoma and melanosarcoma. Their use in chemotherapy is limited owing to issues such as intrinsic glutaminase activity and side effects such as hypersensitivity and organ failure. L-asparaginase is also used as a food processing aid in baked goods to reduce acrylamide formation via Maillard reaction. This warrants investigation of novel and effective L-asparaginases with minimal side effects.

Since the inception of multidisciplinary projects such as the Earth Microbiome Project, Human Microbiome Project and MetaHIT project, there has been considerable interest in the cataloguing of microbial diversity of several environmental niches, with a growing focus on gut microbiomes. Fish gut microbiome is a complex and dynamic ecosystem with an enormous pool of microbial diversity. With 34,300 fish species described till date, fishes comprise nearly half the number of total vertebrates. Fish gut microbiome represents 'worlds within worlds' that are influenced by factors such as host type, trophic level, feeding habits and anthropogenic activities. This niche, however is deeply under explored in terms of community composition and function. The present study seeks to investigate the bioactive potential of *Sardinella* gut microbiome using Illumina Next Generation Sequencing.

Whole meta genome sequencing of *Sardinella* gut microbiome revealed the presence of several diverse enzyme contigs. An L-asparaginase contig was cloned and over expressed in *E coli* BL21 (DE3) cells. The purified asparaginase SlpA was found to be a tetramer with a molecular weight of 120 kDa. SlpA was optimally active at pH 8 and 30°C. SlpA lacks glutaminase activity and has a low Km value of 3.008 μM, making it a potential candidate for cancer treatment and food applications. SlpA showed cytotoxicity against both K562 (chronic myeloid leukemia) and MCF-7 (breast cancer) cell lines. Further, SlpA was evaluated for acrylamide mitigation during baking. Addition of L-asparaginase SlpA to the dough prior to baking considerably reduced acrylamide formation in bread and biscuits. SlpA can therefore be used as an alternative to the existing anticancer drugs and as a food processing aid to ensure food safety during baking.

# Polyhydroxyalkanoate producing bacteria from North eastern Arabian Sea (NEAS)

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Polyhydroxyalkanoates (PHAs) from bacteria are well-studied substitutes of biological origin for the conventional petroleum plastics. Most of the isolates currently used for commercial production of PHAs are of terrestrial origin and the diversity richness of marine environment has not been tapped. Studies on PHA producing marine bacteria are often limited to the isolates from coasts and salt pans, despite the extreme diversity offered by different marine ecosystems. Our study focuses on PHA producing bacteria from the highly productive North Eastern Arabian Sea during the period March 2013.

In this study, 320 PHA producing strains have been isolated, of which 12 have showed notable PHA accumulation based on cell dry weight. Subsequently, 16S rRNA gene sequencing results revealed that these PHA producing isolates belonged to class *Alphaproteobacteria, Gammaproteobacteria* and phylum *Actinobacteria*. The isolates *Donghicola eburneus* MCCB271, *Ruegeria mobilis* MCCB272 and *Labrenzia aggregata* MCCB 275, *Aeromicrobium* sp. MCCB341, *Brevibacterium casei* MCCB276 and *B. casei* MCCB338 were identified as novel PHA producers when glucose was used as the carbon source. All the isolates accumulated PHA between 55 to 70% (w/w) of the cell dry weight when grown in ZoBell's marine broth supplemented with 20 g/l glucose as the carbon source. Characterization of the extracted polymer by Differential Scanning Calorimetry demonstrated a melting temperature (Tm) close to commercial PHA standards.

# Comparison of OnIL, OnIB and OnIF cell lines derived from different tissues of Nile tilapia *Oreochromis niloticus*, Linnaeus, 1758 in the propagation of Tilapia lake virus

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For the effective propagation of viral vaccines and development of diagnostic kits, establishment of fish cell lines are inevitable in the field of sustainable aquaculture. The foremost viral diseases effecting tilapia is Tilapia Lake Virus which is responsible for huge economic losses worldwide. The mass mortality of Nile Tilapia due to Tilapia Lake Virus (TiLV) was reported from West Bengal and Kerala during 2016 by Behera *et al.*, 2018. More studies in TiLV have been hindered as there is no permissive cell line to propagate the virus. In this study, we have developed three different cell lines including OnIL, OnIB and OnIF from liver, brain and fin of nile tilapia respectively to compare the sensibility of the cell line in the propagation of TiLV. All the three cell lines were optimally maintained at 28° C in Leibovitz's-15 medium containing 10% of FBS and have been passaged up to 30, 25 and 28 times respectively. The origin of all three cell lines has been confirmed by amplification and sequencing of 16S rRNA gene and also found to be free of *Mycoplasma* sp. The cytopathic effect (CPE) was first observed in the OnIL cells in 3 day post inoculation (dpi) and complete death of cells occurred 8 dpi. The OnIB and OnIF showed CPE with 5 dpi and 7 dpi respectively. The viral titers of TiLV in OnIL was more when compared to the other cell lines and reached $10^{4.04}$ TCID50/ml. Viral titers were examined from the 6th to the 12th passage of the virus and no obvious difference was observed after 6–12 passages. The presence of TiLV in all the three cell lines was confirmed by the amplification of segment 3 of TiLV gene. Additionally, an experimental infection demonstrated that TiLV produced in OnIL cells caused 90% mortality in tilapia. All the results provide solid evidence that the OnIL cell line is highly permissive for the isolation and propagation of TiLV. This is a significant advancement that will promote additional research on TiLV infection in fish in the future.

# Growth, bioconversion efficiency and nutritional evaluation of black soldier fly *Hermetia illucens* larvae in different substrates–A novel aquafeed ingredient

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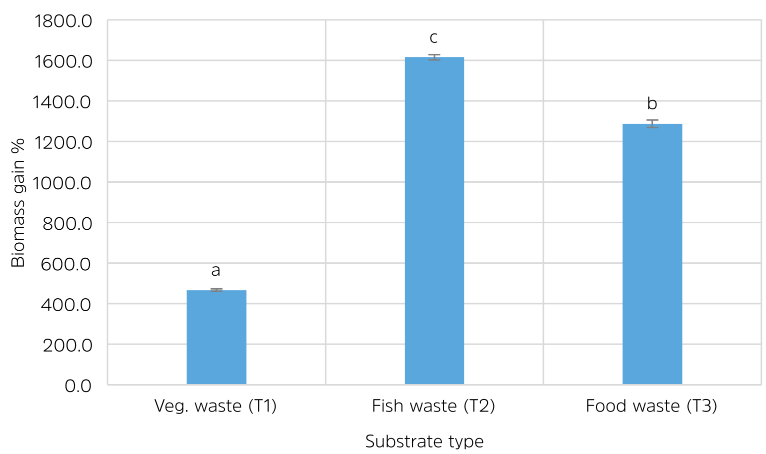
Black soldier fly (BSF) larvae are an excellent means of high value sustainable protein and lipid rich ingredients for aqua feeds due to their good nutrient profile with high protein (> 40 % on dry matter basis) and lipid (>35 % on dry matter basis) depending on the nutritional content and nature of the substrate provided. They are also a preferred nutrient bioconversion agent for organic wastes due to several attributes such as (i) fast and efficient bioconversion, (ii) non-pest nature, (iii) short life cycle with its ability to repopulate quickly and (iv) non-fondness towards human inhabitation. In the present study, three different substrates *viz.*, vegetable waste (T1), whole fish waste (T2) and food waste (T3) were used for the evaluation of growth, bioconversion efficiency and nutritional composition of BSF larvae. 5 days old BSF larval biomass were weighed and distributed equally at the rate of 100 g in the trays provided with substrates (5.3 kg each) for a period of two weeks. The inoculation rate of BSF larvae to substrates was 1:53 w/w in all the treatments. After the study period, larvae were collected, washed to remove debris and weighed. Highest growth and total bio mass of the larvae was observed in T2 followed by T3 and T1. The total biomass gain % of the larvae in T1, T2 and T3 were 467±6.08, 1616±13.20 and 1288.33±19.06 (%) respectively and




Biomass gain % of larvae in different substrates

Proximate composition of BSF larvae reared in different substrates (% DM basis)

| Substrates | Crude Protein | Ether extract | Crude fiber | Total ash | Acid insoluble ash | Nitrogen free extract | Dry matter |
|---|---|---|---|---|---|---|---|
| Vegetable waste (T1) | 49.79±0.14$^{a}$ | 34.79±0.02$^{a}$ | 1.02±0.02$^{b}$ | 10.50±0.20$^{b}$ | 0.71±0.01$^{b}$ | 3.18±0.28 | 29.58±0.51 |
| Fish waste (T2) | 52.44±0.29$^{b}$ | 36.27±0.27$^{b}$ | 0.59±0.01$^{a}$ | 6.06±0.07$^{a}$ | 0.74±0.02$^{b}$ | 3.90±0.21 | 30.60±0.53 |
| Food waste (T3) | 49.75±0.15$^{a}$ | 38.45±0.22$^{c}$ | 0.55±0.02$^{a}$ | 6.51±0.31$^{a}$ | 0.58±0.01$^{a}$ | 4.14±0.53 | 29.01±0.50 |

Note: The values bearing different superscripts in the same column indicate statistical significance (P<0.05), mean± SE, n=3.

differed significantly *(P<0.05)* among the treatments. The average biomass yield of larvae was 0.13, 0.42 and 0.34 in T1, T2 and T3 respectively. Bioconversion efficiency was highest in T2 and lowest in T1. The nutritional composition of the larvae exhibited significant differences among the treatments. The highest crude protein content in larvae was found in T2 (52.44± 0.29, % DM basis) followed by T1 and T3. The lipid content (% DM basis) of larvae in T1, T2 and T3 were 34.79±0.02, 36.27±0.27 and 38.45±0.22 respectively.

# Antioxidant, antibacterial and antibiotic potentiating activities of tropical marine sponge *Spongia officinalis*

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Bioactive compounds which are having distinctive structures and pharmacological properties are gaining great importance these days. Marine ecosystem holds a vast collection of bioactive compounds, which remains unexplored. Among the marine inhabitants, sponges are always unique because of the exclusive bioactive compounds present in them. The indiscriminate use of drugs has led to a frightening increase in drug resistance which is an insisting factor behind drug discovery. Active free radicals can induce oxidation that can lead to severe problems like peroxidation of lipids, damage to membrane proteins that will affect metabolic activities, and damage to DNA that can lead to mutations. It is one cause of various diseases including cancer, cardiovascular illness, and atherosclerosis. Antioxidants with antiradical activity play an important role in preventing the development of these diseases and their treatment. Our study was aimed to explore the anti-bacterial and antioxidant potential of marine sponge *Spongia officinalis*. The marine sponge collected from Kovalam was subjected to sequential solvent extraction using the solvents methanol, ethyl acetate, chloroform, and hexane. These extracts were screened for antioxidant and antibacterial activities. To determine the antioxidant activity DPPH assay, nitric oxide assay, hydroxyl radical scavenging assay, total antioxidant activity, ferric reducing antioxidant power and reducing power assay was performed. Well-diffusion assay, minimum inhibitory concentration (MIC), minimum bactericidal concentration (MBC) and antibiotic potentiating assay was performed to determine the antibacterial potential of the extracts. Among the four extracts, chloroform extract showed potent radical scavenging activity and reducing power capacity compared with other extracts while methanolic extract showed significant antibacterial activity against seven human pathogens with the largest Inhibitory zone diameter (IZD) and lowest MIC/MBC values. Phytochemical screening revealed the presence of alkaloids, steroids, carbohydrates, glycosides, and terpenoids as the major bioactive compounds in the extracts. Sponge is a storehouse of biologically active compounds which is having enormous research potential and further studies can lead to a successful discovery of pharmacologically relevant compound.

# Involvement of serotonin and dopamine receptors in the neuroendocrine mediation of vitellogenesis in *Penaeus indicus*

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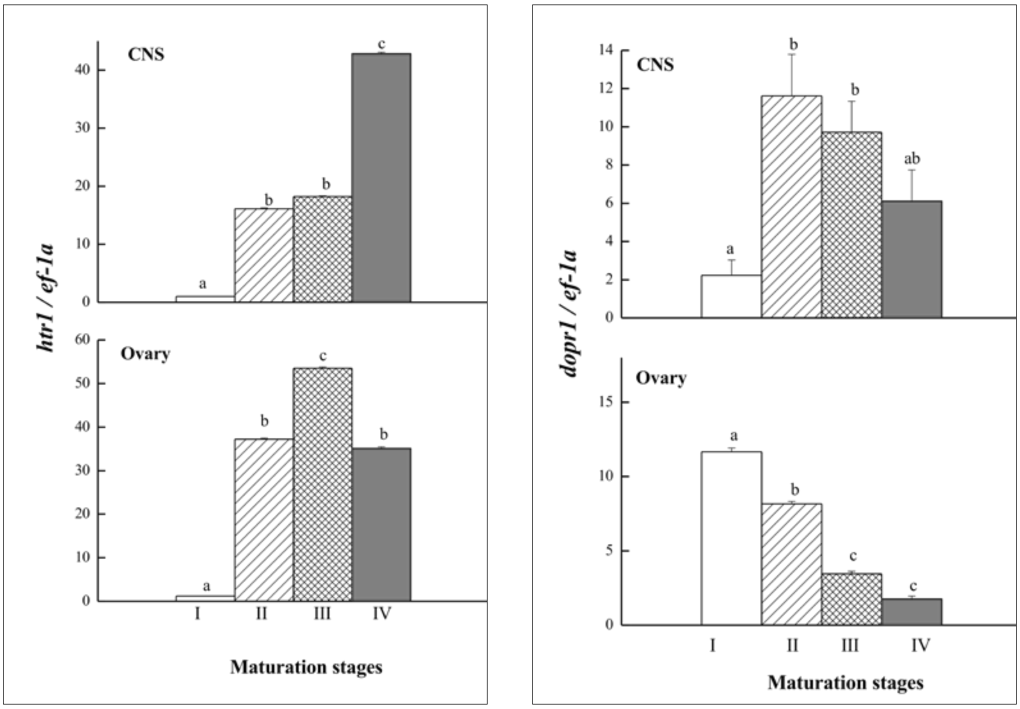
Reproduction in decapod crustaceans is regulated by various neurohormones synthesized and released from the X-organ–sinus gland complex located in the eyestalks, as well as from other neuroendocrine organs and secretory neurons. The upstream control of neuropeptide hormone-release is regulated by biogenic monoamines. Among the five established biogenic amine neurotransmitters, serotonin (5-hydroxytryptamine, 5-HT) and dopamine (DA) are two powerful neurotransmitters that control complex behaviours. Although the complex regulatory mechanism involved in crustacean reproduction is not thoroughly understood, a number of evidences suggest that neurotransmitters play a pivotal role. Serotonin induces ovarian maturation and spawning, and also regulates testicular growth in penaeid shrimps probably by regulating the release of gonad-inhibiting hormone from the XO/SG and/or by enhancing the release of gonad-stimulating hormone present in the nervous tissue. In contrast, dopamine inhibits ovarian maturation, presumably by inhibiting the stimulatory effect of serotonin




Real-time PCR analysis of (a) htr1 and (b) dopr1 transcripts in central nervous tissues and ovaries of wild caught *Penaeus indicus* during different stages of maturation.

on gonad development. The complex serotonin and dopamine signalling systems modulate the release of neuropeptides from the neuroendocrine tissue through membrane-bound G protein-coupled receptors (GPCRs) that in turn stimulates the signal transduction pathway. The differential expression profile of serotonin receptor type 1 (htr1) and dopamine receptor D1-like receptors (dopr1) in ovary and central nervous tissues were analysed in naturally maturing, wild caught and induced maturing female shrimps. The differential expression of *htr1* mRNA level in females undergoing natural ovarian maturation showed an increasing trend with maturation in both ovary and nervous tissues, while the expression levels of *dopr1* was highest in vitellogenic ovaries and in the brain of immature females.

Serotonin treatment (5HT, 50 µg/g body weight) was given to intact (5HT) and unilaterally eyestalk ablated (5HT + ESA) females and the expression of *htr1* and *dopr1* in the treated shrimps was compared with the control and eyestalk ablated shrimps (ESA) on Day 7 and 14. Quantitative real-time PCR indicated that the levels of *htr1* increased significantly in ESA and 5HT + ESA groups. On the other hand, expression of *dopr1* was high in eyestalk intact group and was significantly low in the eyestalk ablated shrimps. The results suggest a key role for both dopamine and serotonin receptors in coordinating the hormonal signalling pathway to regulate maturation. Further research is required on the synergistic interaction of serotonergic and dopaminergic pathways to understand the receptor mediated signalling mechanisms regulating gonadal development in penaeid shrimps.

# Reduced genetic diversity in oceanic White tip sharks (*Carcharhinus longimanus*) calls for urgent management measures

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Sharks are facing the risk of extinction worldwide and hence it is very important to assess the population status and intra-specific genetic diversity. Oceanic white tip sharks are large pelagic sharks distributed circumglobally and IUCN assessments indicated their status as "vulnerable" globally and "critically endangered" in the Western North and Central Atlantic oceans. Indian Ocean region is one of the hot spots of biodiversity, but genetic information regarding many important sharks is insufficient. Considering the vulnerability and data deficiency with respect to oceanic white tip shark, *Carcharhinus longimanus*, we investigated the intra-specific diversity and genetic structuring of this important shark along the Indian coast using mitochondrial control region sequences for formulating viable management plans. A lack of significant population structuring along the Indian coast in population genetic analyses indicated substantial gene flow and connectivity among populations. The pattern of Bayesian skyline plots indicated ancient population expansion followed by a contemporary reduction which demands urgent management measures for this species. Extensive gene flow and connectivity between Indian and East Atlantic regions and a lack of connectivity between Indian and West Atlantic regions was apparent when control region sequences of the present study were compared with NCBI GenBank data. The capacity of Oceanic white tip sharks to migrate across continental margins especially along Indian and east Atlantic regions was evident from the present investigation. In spite of these capabilities, a decline in contemporary effective population size is a warning sign of their possible extinction and it is imperative to devise management and conservation measures. Restrictions can be imposed on their fishery at the earliest so that populations get sufficient time to replenish and enhance their resilience towards climate change and habitat alterations.

# Parasitic ciliate, *Trichodina* sp. infestation, its treatment and control measures in Cobia fingerlings (*Rachycentron canadum*) at Mandapam, Tamil Nadu

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A total of 21,000 cobia fingerlings with a mean total length of 17.08 ± 2.34 cm and a mean weight of 20.53 ± 4.86 g were nursery reared in four 100 tonne capacity RAS tanks. During April 2019, few cobia fingerlings showed clinical signs like sluggishness, slow and disoriented swimming, frequent surfacing, off feed, and rubbing of opercula on the wall of tanks. Severely affected fish settled at the bottom of the tank and the death toll rose gradually to 480 numbers within 48 hours. Gross examination of the dead fish revealed abrasions in the operculum, with profuse mucous secretions from the gill. Few severely affected cobia fingerlings showed bleeding from the gills. The caudal and dorsal fins also showed erosions. Microscopic observation of gills revealed the presence of parasitic ciliates firmly attached to the gill lamellae and was identified as *Trichodina* sp. Histological examinations showed the attachment of *Trichodina* on secondary gill lamellae causing localised necrosis and erosion. The affected cobia fingerlings were treated with "Bioline Plus" (SDC Agro-Vet India Pvt. Ltd.,) consisting of disinfectants in a combination of Formaldehyde, Gluteraldehyde and Benzalkonium chloride. Bioline Plus was applied at the rate of 10ml/1tonne of tank water and maintained up to 1 hour. After that 90% water exchange was carried out. Within 24 hours of treatment, all the cobia fingerlings recovered and no further mortality was observed. The swarming of *Trichodina* sp. ciliates was recorded during the summer months. The acute mortality (2.3%) of cobia fingerlings might be due to hypoxia. The excessive numbers of *Trichodina* sp. on the gills of infected fish might have interfered with respiration of the fish. Nearly 20,500 cobia fingerlings maintained in four 100 tonne tanks were saved by timely treatment and management strategies.

# Multi-factor multi-stratum response surface design for process optimization in fisheries

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The major processes involved in fish culture and fish processing are hatching, feed formulation, curing, salting, drying, smoking, canning, marination, extraction, biosorption, biosynthesis, coagulation, fermentation etc. The significant factors affecting the underlying process conditions are temperature, photoperiod, salinity, time, pressure, air velocity, stocking density, dissolved O2 content, water depth, nutrient level of feed, rate of water circulation, fillet thickness, salt concentration, moisture content, enzyme to substrate ratio, extraction solvent, stirring speed, extruder screw speed, fish oil content etc. To have effective production, finding the optimum condition of factor setting for mentioned process is mandatory. The classical one factor at a time (OFAT) approach may not be useful for such situations as it examines only one parameter at a time while keeping other parameter constant and fails to obtain interactions. It is too common to employ Response Surface Methodology (RSM) for searching the experimental setting which produces optimum response under a multifactor setup. It starts with a response surface design with randomized run sequence

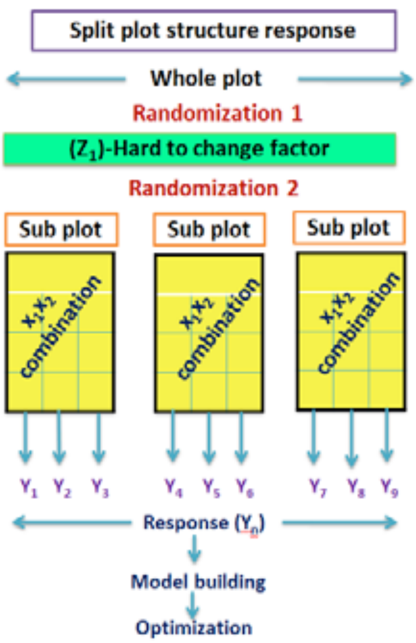


Fig 1. Response surface with one HTC factor ($Z_1$) and two ETC ($X_1$ and $X_2$)

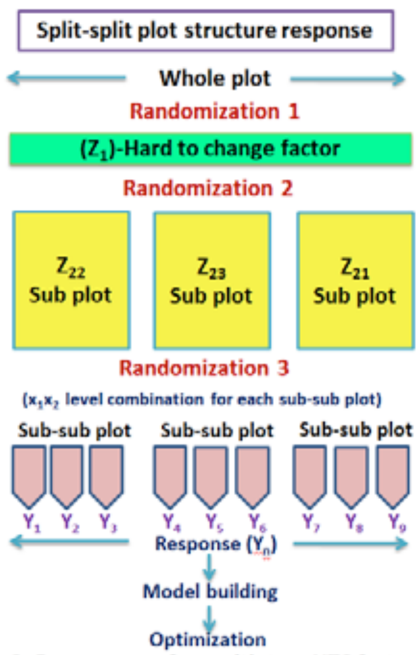


Fig 2. Response surface with two HTC factor ($Z_1$ and $Z_2$) and two ETC factor ($X_1$ and $X_2$)

and then building an appropriate approximate relationship between response and input variables and finally optimization. In the process, some of the input factor levels may be difficult or very costly or hard-to-change (HTC) frequently. Thus the use of RSM for obtaining optimum response through use of completely randomized response surface design viz., Central Composite Design (CCD) and Box- Behnken Design (BBD) with hard to change factors are more expensive and time consuming. To resolve the problem experimenter usually restrict the randomization over HTC factor (fixing the level) and run all other easy-to-change (ETC) factor combination randomly with respect to each HTC factor level. This criterion implies split design nature where experimental units are subdivided into whole plot for HTC factor level and sub plot for ETC factor level. The HTC factors are assigned randomly to whole plot and within each whole plot, all ETC combination are assigned randomly for subplot which tends to two type randomization as split plot design. When the number of HTC factor is more than one, then design extend its randomization restriction to multi-stratum which forms multi-factor multi-stratum response surface design.

When the experiment having one HTC factor and two ETC factor, then the nature of response structure will be identical as split plot structure (Figure 1) with two stages of randomization (HTC factor level on whole plot randomization and two ETC factor level combination on sub plot randomization within each whole plot). This design extends to split-split plot structure (Figure 2) for the situation having two HTC factors and two ETC factors, which tends to three stages of randomization (first HTC factor level on whole plot randomization, second HTC factor level on sub plot randomization within each whole plot and two ETC factor level combination on sub-sub plot randomization within each sub plot). An important consequence is that one cannot use the ordinary least squares (OLS) to estimate the parameters of the model. This leads to the use of restricted maximum likelihood (REML) and further the optimum factor setting for the process can be obtained.

This paper explores the modified CCD and BBD design having minimal level change suitable for multi-factor hard-to-change factor experiment. The estimation of optimum response under this situation in fisheries is illustrated with example.

# Mixture experiment for product optimization in fisheries

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In fisheries, in experimental situations such as fish feed formulations, the response is based on the proportion of input ingredients used in product development. In such case the use of classical one variable at a time (OVAT) approach will be ineffective as it examines only one component while keeping others at constant level and fails to provide interaction information. It may be of interest to know the best mixture of ingredients (say for example: protein, lipid and carbohydrate) in a fish diet. In such situations, the intuitive OVAT approach has to be replaced by a special type of response surface design called mixture experiments which is very effective in determining the proportions of variables in a blend. The peculiarity of mixture experiment is that it accommodates the experiment consisting of relative proportion of the input factors which is summing up to one, along with resource and/ or cost constraints. Some of the experimental situations where mixture experiments can be employed are feeding trial experiments in fisheries, fish processing, sensory trials etc. The quality of end product in a mixture experiment depends on the relative proportion of each component in the mixture. Mixture experiment plays a wide range of roles in product development studies. The most widely used mixture designs are simplex- lattice designs, simplex-centroid design, simplex axial design and extreme vertex design. Simplex centroid designs can be used as alternatives to simplex lattice designs, when all the components have the same range (between 0 and 1) as well as in a nonexistent constrained design space. In case of constrained mixture, the experiment can be achieved by using optimal designs. A simplex centroid design can be used to optimize the different protein combinations of a fish meal diet. In order to determine the effects and interactions of the seasoning mixture containing fish protein powder/fish oil, an optimal design can be used. An optimal mixture design with multiple response optimisations utilising a polynomial would successfully employ the optimisation of formulations. This paper attempts to explain the optimization of ingredients for fish meal diet using mixture design.

# Molecular phylogenetic analysis reveals separate clades for Scombroids and Xiphioids

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Genetic information is considered dependable for the efficient implementation of strategies to learn evolutionary relationships, phylogeography and phylogeny and forms the basis for the protection and management of biological diversity. Mitochondrial DNA is of particular interest over nuclear genome due to its maternal mode of inheritance, rapid divergence, high linkage rate and lack of recombination. The taxonomic classification and phylogenetic relationships of the suborder Scombroidei (Perciformes) remains controversial. Numerous rearrangements have been done in the suborder since Regan proposed the first modern definition of the group based on three primary characters: premaxillae beak like, gill membranes free from the isthmus, and epiotics separated by the supraoccipital. Repeated attempts have been done to resolve intra and inter-relationship of the suborder. It is generally accepted that Scombroidei comprises six familes viz., Istiophoridae, Xiphiidae, Scombridae, Sphyraenidae, Gempylidae and Trichiuridae. At the center of the debate surrounding Scombroid phylogeny are the highly migratory Billfishes, comprised of the monotypic Xiphiidae and the monophyletic Istiophoridae. They are fast moving, have remarkable physiological adaptations related to regional endothermy, exhibiting muscular, metabolic and cardiovascular specializations for increased aerobic capacities and continuous swimming which are not shared by other Scombroids.

Morphological phylogenies are more prone to type I error due to increased chance of misinterpreting adaptive convergence indicating a need for a molecular based study. Partial mitochondrial fragments however, exhibit limitations to resolve complex phylogenetic relations in fish lineages. Hence, a wider taxonomic sampling and additional informative sites from longer DNA sequences (e.g., mitogenomes) to represent the extremely complex patterns of diversification of Scombroidei is essential. Hence, we characterized the complete mitogenome of Ribbon fish, *Trichiurus lepturus* (largehead hairtail) by PCR amplification and sequencing. *T. lepturus* is a benthopelagic species found from continental shelf to inshore waters of about 350 m in depth and is widely distributed in the Indian Ocean.

The entire mitogenome is 16,840bp in length, shared the features with the other bony fishes and has 13 protein coding genes (ND1–6 and 4L, COI–III, ATPase6 and 8, Cytb), 2 subunit ribosomal RNA genes (12SrRNA and 16SrRNA), and 1control region. A phylogenetic tree was reconstructed using thirteen Protein Coding Genes of 36 individuals belonging to six families of the suborder Scombroidei for the purpose of analysing the evolutionary relationship among the scombroid fishes. Mitogenome of *Callorhinchus milii* of the order Chimaeriformes was used as outgroup. Bayesian and Maximum Likelihood analysis (ML) produced trees with identical topologies having similar branch lengths, strong bootstraps (ML) and posterior probability (Bayesian) values.

Our phylogenetic analysis revealed that *T. lepturus* belonged to the family Trichiuridae of the suborder Scombroidei and is closely related to *T. japonicus* with a higher posterior probability value of 1. Monophyly of Scombroidei is not supported since Billfishes and Scombroidei form separate clades against the classical Scombroidei which is based on morphological characters. Our results suggest that Billfishes and Scombroids are not similar and should be placed in a separate suborder, Xiphoidei (non-scombroid hypothesis) providing evidence to polyphyly supported by the differences in the sperm microstructure and developmental and meristic characters. Similar traits between Billfishes and Scombroids viz., physiological, morphological and anatomical muscular adaptations related to continuous swimming and regional endothermy may have arised, not due to monophyly, but from convergent evolution. Further, advanced studies on population genetic structure, phylogenetics and adaptive evolution also can be carried out based on insights from this investigation.

# Isolation and characterization of a Xylated glycosaminoglycan with bioactive potentials from the Buccinid gastropod mollusc *Babylonia spirata*

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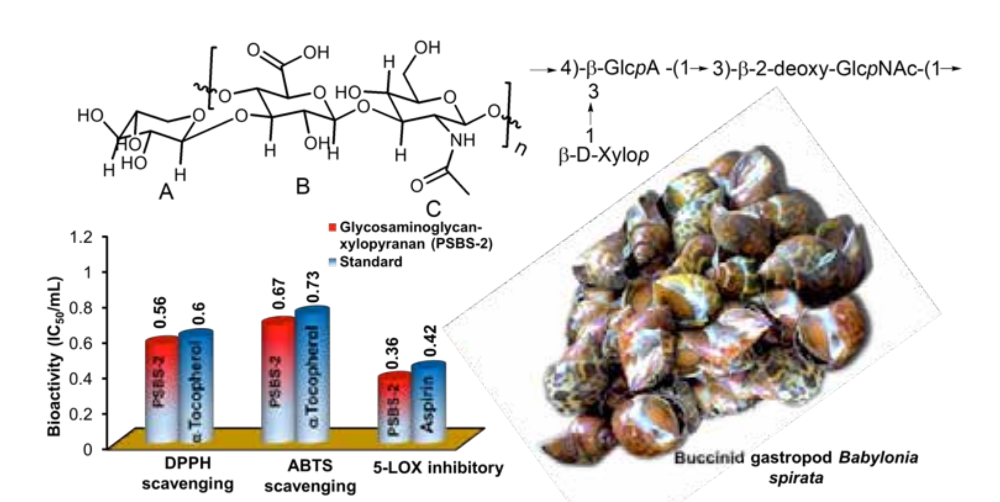
The polysaccharides of marine origin are gaining wide attention in the recent years, due to their promising pharmacological applications. Polysaccharides from molluscs are reported for their potent antioxidant, anti-inflammatory and hepatoprotectic activities (Jiang *et al*., 2011; Mikheiskaya *et al*., 1988) *Babylonia spirata,* a gastropod mollusc of the family Buccinidae, is a species of economic prominence in peninsular India. The buccinid gastropod is noted for its nutritional features and pharmaceutical potential of small molecular metabolites (Chakraborty *et al*., 2019; Salas & Chakraborty, 2018).

This study reported the isolation and structural characterisation of a xylated glycosaminoglycan from the edible part of the marine gastropod mollusc *Babylonia spirata.* The structural information of the purified polysaccharide was determined by a combined spectral analysisusing Fourier Transform Infrared (FTIR) and Nuclear Magnetic Resonance (NMR) spectrometric techniques. Theanomeric configuration, linkage sites and the sugar residuesequence of the purified polysaccharide were unravelled by the two dimensional nuclear resonance spectroscopic techniques.

*In vitro* anti-inflammatory property of the crude polysaccharide (CPSBS) obtained from the




**a xylated hyaluroan from the buccinid gastropod mollusc *Babylonia spirata* with pro-inflammatory 5-lipoxygenase attenuating activity**

buccinid gastropod and the oligosaccharide fractions were evaluated by studying the inhibition of pro-inflammatory 5-lipoxygenase (5-LOX) (Baylac & Racine 2003) enzyme. The CPSBS was successively purified by chromatography over an ion exchange column loaded with DEAE-52 adsorbent material (Mao *et al*., 2008; Li *et al*., 2011).Monosaccharide compositions of the purified fractions were determined by the trifluoroacetic acid hydrolysis method followed by HPLC analysis using ELSD detector (Montesano *et al*., 2016). The crude polysaccharide (CPSBS) contained 65.86 % of total sugar and 42.55 % uronic acid, whereas the protein and sulfate contents were 8.30 % and 13.8 %, respectively. The monosaccharide composition analysis by the HPLC-ELSD method specified the fraction PSBS-2 had simpler monosaccharide composition consisting of xylose and glucose derivatives of N-acetyl glucosamine and glucuronic acid when compared against the crude polysaccharide CPSBS and the remaining oligosaccharide fractions. The average molecular weight of PSBS-2 fraction as determined from the calibration curves of dextran standards was calculated as 231.883 kDa. The results specified that the studied compound was composed of Glc*p*A(1→3)-Glc*p*NAc (1→···) disaccharide repeating unit in the backbone, with the xylose units branching as C-3 substituents of the Glc*p*A in the backbone glycosaminoglycan. The xylated glycosaminoglycan characterised as β-D-Xylo*p* (1→3)-(···→4)-Glc*p*A(1→3)-Glc*p*NAc (1→···) was further evaluated for pharmacological properties using different *in vitro* models.

The purified xylated glycosaminoglycan displayed potential inhibitory activities (IC50 0.36 mg/mL) against pro-inflammatory enzyme 5-LOX when compared to the standard Aspirin (IC50 0.93 mg/mL).The xylated glycosaminoglycan was found to be a prospective inhibitor of free radicals and could successfully inhibit the pro-inflammatory enzyme lipoxygenase-5 and hence be used as nature-derived bioactive component in functional food and pharmaceutical applications.

# Morphological and molecular characterization of *Auerbachia ignobili* n. sp. from *Caranx ignobilis* (Forsskål, 1775), with a note on its development

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Myxozoans are obligate endoparasites belonging to the phylum Cnidaria, completing their lifecycle in invertebrate and vertebrate hosts. Genus *Auerbachia,* established by Meglitsch (1968) is a relatively small genus with 12 nominal species. During a survey for myxosporean parasites in food fishes along the southwest cost of India during 2015-2019, a new species of *Auerbachia* was observed infecting *Caranx ignobilis*. Samples of *C. ignobilis* were collected from the coastal waters off Goa, Karwar, Kozhikode, Mangalore, Ernakulum and Alappuzha along the west coast of India.

Both gallbladder contents and liver harboured *Auerbachia* infection. Overall prevalence of infection stood at 78.86% and seasonal variations in prevalence were observed. Mature spores measured 17.43± 1.49 (15.48-19.73) ×7.47 ±7.37 (6.66-8.45) μm while caudal extension measured 6.79±0.79 (5.62- 7.82) μm with an extension angle of 143.24 ± 4.59 (138.10 – 146.93) $^{0}$. Polar capsule measured 7.17 ±0.36 (6.69-7.74) × 2.93±0.30 (2.50-3.46) μm, polar filament with 4-5 coils and measured 58.65±8.56 (40.79-66.18) μm. Develpomental stages including presporogonic stage, pansporoblast, and monosporic and diasporic plasmodia were observed in the liver. In histology, parasites or its developmental stages were not observed with in the liver cells, instead the developmental stages and adult spores were seen in the bile capillaries of the liver. In gallbladder, large number of free floating, mature spores were observed, but developmental stages were absent. Fluorescent *In situ* Hybridisation (FISH) studies performed with genus specific primer clearly indicated the presence of parasites in bile capillaries confirming its development in the liver. In Scanning Electron Microscopy (SEM) studies, spore surface appeared smooth with an asymmetrical suture and the point of polar capsule ejection appeared raised with a slightly pointed anterior region.

Partial sequences of SSU rDNA gene of the parasite were deposited in GenBank (MN688747, MN688754, MN688749, MN688750, MN688753, MN688751, MN688755, MN688756, MN688752 and MN688748). In BLASTN analysis, the sequences showed highest identity (94.60 – 93.73%) with *A. maamouni* isolated from *Gnathanodon speciosus.* Intraspecies identity between the isolates of the present parasite from various locations ranged from 99.1% to 100 indicating its conspecific nature. The highest interspecies identity observed was 93.3% with *A. scomberoidi*. Maximum likelihood and Bayesian Inference analyses showed similar tree topologies and placed the present myxosporean under the *Auerbachia* clade along with species of the family Coccomyxidae with high bootstrap value (0.8/93). The present parasite occupied an independent position within the *Auerbachia* sub-clade with high bootstrap value (1/100) in both the trees. Morphology, morphometry, host, organ of infection, geographic location, and molecular and phylogenetic studies clearly separate the present species from already described species of *Auerbachia.* Hence, the present species is treated as new and the name *Auerbachia ignobili* n. sp. is proposed.

Theme-5 Marine biotechnology and bio-marine products
(disease detection, surveillance and control)

# Characterization of bioactive properties of polysaccharide-like compound from marine mollusc *Perna viridis*

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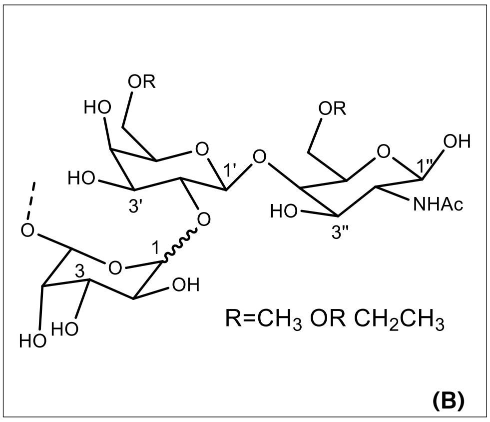
Marine polysaccharides have been found to possess a variety of biological activities and have drawn great academic attentions in biochemical and medical areas, which show a broad prospect for development as nutraceuticals and pharmaceuticals. More importantly, many of the natural polysaccharides are found to be effective and relatively nontoxic substances. Polysaccharides derived from aquatic animals are, Glycosaminoglycans (GAGs) which include heparin, heparan sulphate, dermatan sulfate (DS), chondroitin sulfate (CS) and keratan sulfate (KS) and they perform a variety of biological functions and play an important role in a number of different diseases. And they reduce pain and inflammation, improves joint function and slows progression of osteoarthritis (OA). These effective activities of GAGs are triggered by interaction with proteins. Hyaluronic acid (HA) is the most important form of glycosaminoglycan and it is involved in several cellular functions, including cell proliferation, cell locomotion, and interactions with leukocytes. HA is used clinically the treatment of joint disease, in ophthalmic surgical devices, and in wound healing. The chondroitin sulfates and heparan sulfates appear to be widely distributed in the class Bivalvia of molluscs. The focused of the study was to utilize the biologically active Glycosaminoglycans from the species *Perna viridis* for biomedical applications such as immunomodulating, anti-inflammatory, antioxidant, and anticoagulant, antitumor. The structural analysis of polysaccharide gives more understanding of biological applications and also which helps in the development of structure-activity relationship for these active biopolymers. This study also possessed the purification and structural characterization of pure polysaccharide moiety from bioactive *Perna viridis.* The anion exchange column chromatographic was used to isolate pure bioactive polysaccharide from *Perna viridis* by the aid of DEAE (Diethyl aminoethyl) cellulose resulted six fractions and which was further made into powder by lyophilization. The eluted fractions were tested for positive reaction of polysaccharide by phenol-sulphuric acid assay. The column fraction designated


(A) *Perna viridis* (B) The structure of GAGs (2→1)-β-D-fucopyranosyl-(1→4)-α-D-galactoaminopyranosyl-glucopyranose of *Perna viridis*.

as PV-2 recorded greater percentage of carbohydrate (57.2%) and a considerable amount of protein (9.19%) compared to other fractions. The monosaccharide composition analysis of purified polysaccharide PV-2 fraction was carried out using the HPLC-ELSD method by complete acid hydrolysis using 2M Trifluoroacetic acid and is compared with standards. The retention time of analyte was consistent with glucuronic acid and glucose and the chromatogram indicates the polysaccharide is a glycosaminoglycan (GAG) type polymer. The NMR data revealed that the polysaccharide skeleton of *Perna viridis* is made up of (2→1)-β-D-fucopyranosyl-(1→4)-α-D-galactoaminopyranosyl-glucopyranose unit.

# Natural anti-inflammatory compounds isolated from *Gracilaria salicornia*: Attenuate 5-lipoxygenase activity

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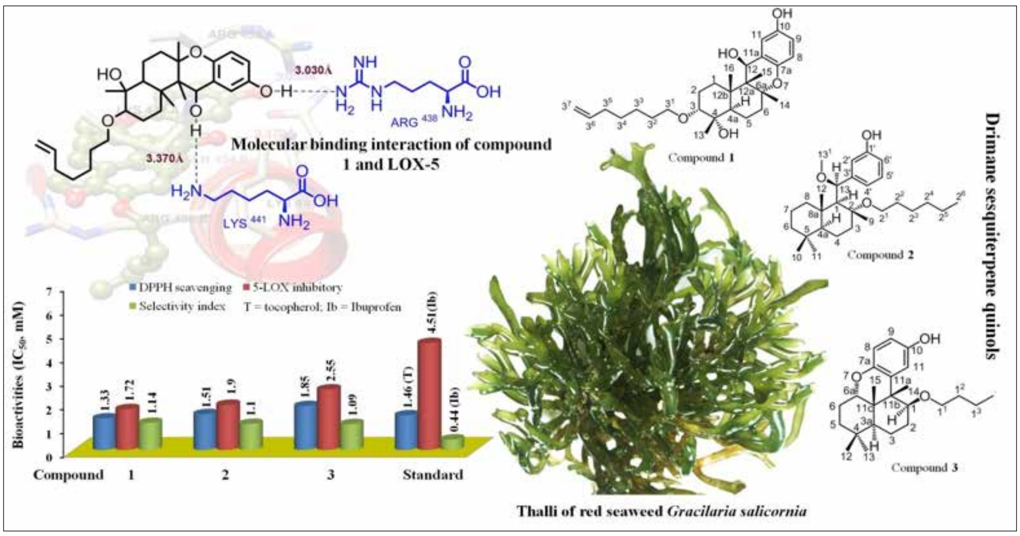
The 5-lipoxygenase-associated cascade has appeared as potential therapeutic target to attenuate inflammatory pathologies. Progression and pathophysiology of inflammation have also shown potential involvement of oxidative stress and inflammatory pathways. Three drimane sesquiterpene quinols, characterised as 3-(hept-3$^{6}$-enyloxy)-decahydro-4,6a,12a,12b-tetramethyl-1*H*-benzo[*a*]xanthene-4,10,12-triol (1), 13-[[2-(hexyloxy)-2,5,5,8a-tetramethyldecahydro-1-naphthalenyl](methoxy)methyl]benzenol (2), and 1-butoxy-4,4,11b,11c-tetramethyl-decahydro benzo[*kl*] xanthen-10-ol (3) were purified from the solvent extract of intertidal marine macroalga *Gracilaria salicornia*, obtained from the southeast coastal region of Indian peninsular. The 1*H*-benzo[a]xanthene-triol derivative (1) registered potential activities against pro-inflammatory 5-lipoxygenase (IC50 1.7 mM) and free radicals (IC50 1.3-1.5 mM). The *in silico* molecular modelling studies to designate 5-lipoxygenase inhibitory mechanism of the studied analogues and the comparison of docking parameters attributed that the drimane sesquiterpene 1 exhibited least binding energy of -12.30 kcal mol$^{-1}$, and showed effective hydrogen bonding interactions with the catalytic site of the enzyme.

The higher electronic parameters and permissible hydrophobic-hydrophilic balance of the drimane sesquiterpene bearing 1*H*-benzo[*a*]xanthene-triol moiety (1) appeared to constitute significant roles




Natural drimanes isolated from *G. Salicornia*. Bioactive potentials of drimanes were plotted in the graph. The molecular binding interactions of compound 1 in the active catalytic site of 5-LOX deduced from the molecular docking simulations towards the attenuation of pro-inflammatory 5-lipoxygenase. These results demonstrated that the drimane-type sesquiterpenoids with 1*H*-benzo[*a*]xanthene-triol framework could be used as a potential therapeutic agent for the treatment of 5-lipoxygenase-mediated inflammatory pathologies. Sesquiterpene class of quinols and quinons with bicyclic drimanes or their rearranged derivatives derived from mixed-biogenesis were prominent in marine natural products. Most of these sesquiterpenes were characterized from marine algae, sponges, and microorganisms. These secondary metabolites were reported to possess potential medicinal properties, including antitumor, anti-inflammatory, antioxidant and antibacterial activities. The seaweeds (or marine macroalgae) of genus Gracilaria sp. were found to produce secondary metabolites, such as steroid and terpenoid derivatives with potential biological activity. Gracilaria sp. are abundantly available in the coastal peninsular India with more than 300 reported species, and were recognized in industrial biotechnology due to the commercial product phycocolloid widely used in food, pharmaceutical and cosmetic industries.

# Pharmacological screening of commonly edible cephalopods from cochin, Southwest coast of India

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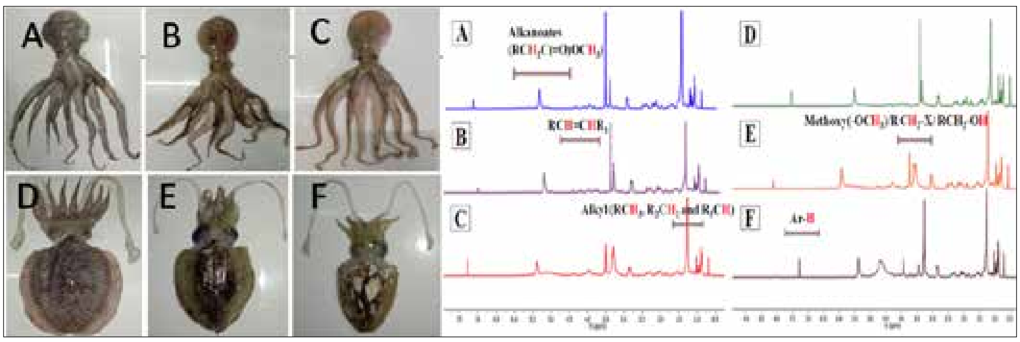
Marine molluscs have emerged as an important repository of numerous unique secondary metabolites and thus become the focus of many chemical studies aimed at isolating and identifying diverse bioactive compounds having therapeutic applications. Pharmacological potential of crude ethyl acetate-methanol (EtOAc:MeOH) tissue extract of economically important six cephalopod species, namely *Cistopus indicus, Amphioctopus marginatus, Amphioctopus aegina, Sepia pharanois, Sepia elliptica* and *Sepia aculeata* were evaluated using various *in vitro* models for antioxidant, anti-inflammatory, anti-diabetic, anti-hypertensive and anti-hypercholestremic assays.

The EtOAc:MeOH extract of *S. aculeata* registered greater DPPH radical scavenging ability (IC90 2.10 mgmL$^{-1}$), Cyclooxygenase (COX-1, COX-2) inhibitory activity (IC90 1.77,1.76 mgmL$^{-1}$) and angiotensin converting enzyme-I inhibitory property (ACE-I) (IC900.88 mgmL$^{-1}$) compared to other investigated cephalopod species. However, 5-lipoxigenase (5-LOX) activity was greater exhibited by *C. indicus* (IC90 1.05 mgmL$^{-1}$) than other cephalopods (IC90>2.0 mgmL$^{-1}$). The organic crude extract of *A. marginatus* demonstrated greater dipeptidyl peptidase-4 (DPP-4) activity (IC90 1.83 mgmL$^{-1}$), ferrous ion chelating ability (IC90 2.25 mgmL$^{-1}$) and were effective in neutralizing ABTS$^{+}$ (IC901.07 mgmL$^{-1}$).Total phenolic content also found to be greater in *A. marginatus* (84.2 mg GAE/g). A. *aegina* exhibited greater H2O2 scavenging (IC900.25 mgmL$^{-1}$) along with potential (HMGCR)-inhibiting activity (IC90 1.54 mgmL$^{-1}$). The EtOAc:MeOH fraction derived from *S. elliptica* shows greater antidaibetic activities, α-amylase, α-glucosidase (IC90 1.02.2.26 mgmL$^{-1}$).

IdentifIcation of the signature peaks and signals of various imperative functional groups responsible for the crucial bioactive



The representative photographs of six cephalopod species, (A) *Cistopus indicus,* (B) *Amphioctopus marginatus,* (C) *Amphioctopus aegina,* (D) *Sepia pharanois,* (E) *Sepia elliptica* and (F) *Sepia aculeata* and stacked plot of $^{1}$H NMR spectra representing the crude EtOAc:MeOH extract of cephalopods species (A) *Cistopus indicus,* (B) *Amphioctopus marginatus* (C) *Amphioctopus aegina*, (D) *Sepia pharanois* (E) *Sepia elliptica* (F) *Sepia aculeata.*

properties were carried out using spectroscopic analyses. The $^{1}H$ NMR spectra of the EtOAc-MeOH fractions of the above six cephalopods exhibited significant co-linearity between the bioactive properties and electronegative functionalities recorded in the deshielded region of the nuclear magnetic resonance spectra of the crude extracts. Application of molluscan species as a key source to develop bioactive pharmacophores for use as functional food supplements to prevent the occurrence of oxidative stress induced diseases such as, diabetes, inflammatory and hypertension disorders.

# Bioactive cyclic ether containing macrocyclic derivatives from brown algae *Turbinaria conoides*

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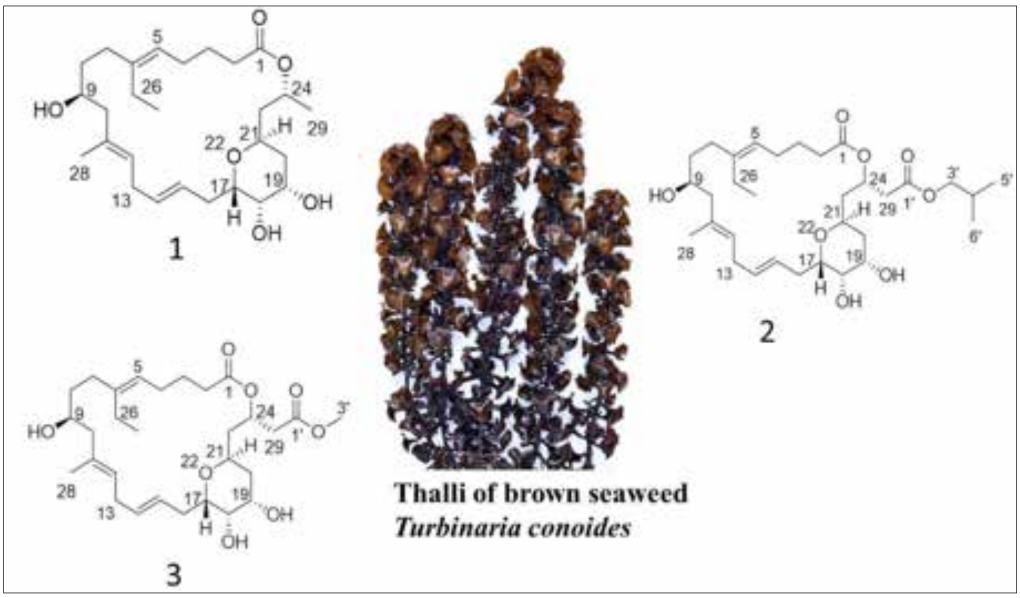
Macrocyclic derivatives inhabit distinctive type of natural products and their chemical diversity was expanded significantly. The structural features of macrocyclic (a ring containing 12 or more than 12 membered) natural products was prearranged in such a way, which led to the interaction with the extended protein binding site by their key functional motifs (Driggers *et al*. 2008). Due to its complex structural diversity, macrocyclic derivatives had received an intense interest among pharmaceutical and medicinal chemistry community. The bioactivity of macrocyclic compounds had been reported (Newman *et al*. 2014). Two novel α-pyrone macrolides were isolated from the Fijian red algae *Neurymenia fraxinifolia* (Stout *et al*. 2009). Twelve membered macrolides (sporiolide A and B) were isolated also reported from the brown algae *Actinotrichia fragilis* derived fungus, *Cladosporium* sp. (Shigemori *et al*. 2004).

Marine brown algae *Turbinaria conoides* (family sargassaceae) is one of the largely abundant species, distributed in the coastal region of the Indian subcontinent. The present study envisaged isolation and characterization of three previously undescribed cyclic ether containing macrocyclic derivatives from the organic extract (ethyl acetate:methanol) of *T. conoides* as, 6-ethyl-9,18,19-trihydroxy-24,28-dimethyl-22,25-dioxabicyclo[19.3.1] pentacosa-5,11,14-triene-1-one (1), (6-ethyl-9,18,19-trihydroxy-28-methyl-22,25-




Representative photograph of the thalli of brown algae *Turbinaria conoides* and structures of macrocyclic derivatives (compounds 1-3) isolated from *T. conoides*.

dioxabicyclo[19.3.1]pentacosa-5,11,14-triene-1-one-29-yl)isobutyl acetate (2), (6-ethyl-9,18,19-trihydroxy-28-methyl-22,25-dioxabicyclo[19.3.1]pentacosa-5,11,14-triene-1-one-29-yl)methyl acetate (3). The chemical structures of the titled compounds were solved by extensive spectroscopic techniques such as, such as one-dimensional and two-dimensional NMR, FT-IR and mass spectroscopic experiments. The macrocyclic lactone, (2) exhibited significantly greater antioxidant properties as determined by 2,2-diphenyl-1-picrylhydrazyl (IC50DPPH 0.42 mg $mL^{-1}$) and 2,2'-azino-bis (3-ethylbenzothiazoline-6-sulphonic acid) (IC50 $ABTS^{+}$ 0.49 mg $mL^{-1}$) than other studied compounds (1 and 3) (IC50 > 0.50 mg $mL^{-1}$) and the commercial standard $\alpha$-tocopherol (IC50 0.65 mg $mL^{-1}$). The compound 2 exhibited greater anti-inflammatory potentials as identified by the lower IC50 for 5-lipoxygenase inhibitory assay (IC50 1.01 mg $mL^{-1}$) than 1 and 3 (IC50 > 1.01 mg $mL^{-1}$) and non-steroidal anti-inflammatory drug, ibuprofen (IC50 0.93 mg $mL^{-1}$). The target bioactivities of the titled analogues were justified with the help of structure-activity relationship study using various physicochemical parameters.

Theme-5 Marine biotechnology and bio-marine products
(disease detection, surveillance and control)

# Antioxidant and anti-inflammatory macrocyclic pyrone derivatives from Echinoidea sea urchin *Stomopneustes variolaris*

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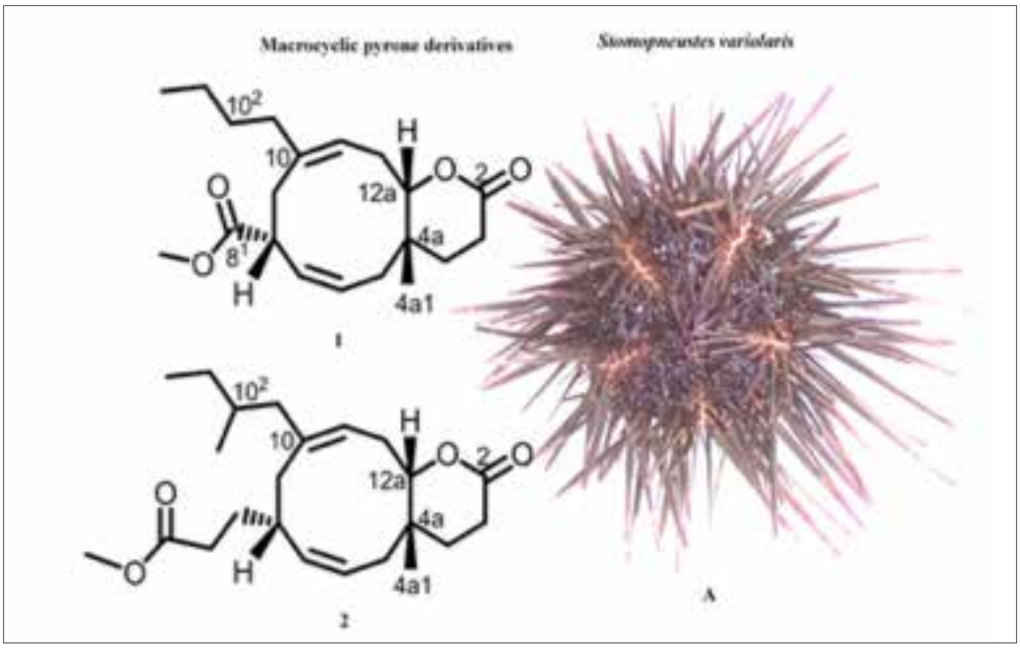
Macrocycles compounds of natural origin containing twelve or more member ring are structurally diverse, and have demonstrated as important sources of pharmacologically active compounds (Montaser and Luesch 2011). This group of compounds was ubiquitous in various marine organisms, and has been endowed with potential medicinal properties. Notably, a large number of marine originated oxygenated heterocyclic containing macrocyclic-type of compounds was known to exist in the previous reports of literature, and were reported to possess valuable pharmaceutical traits. The echinoidea sea urchin *Stomopneustes variolaris*, which is an edible and commercially exploited sea urchin species, is ubiquitous in the coastal and marine waters of peninsular India, even though very few bioactive compounds were reported from this species. The present study depicted the purification and characterisation of macrocyclic pyrone compounds from the organic (ethyl acetate:methanol) extract of *S. variolaris*.

Two new 14-member macrocyclic pyrone derivatives were isolated from the organic extract of *Stomopneustes variolaris* by extensive chromatographic purification. The




(A) Samples of *S. variolaris* and isolated compounds, 1, 2 compounds were characterized as methyl 10-butyl-4a-methyl-2-oxo-octahydro-2*H*-cyclodeca[b]pyran-8-carboxylate (1) and methyl $8^2$-(4a-methyl-10-(102-methylbutyl)-2-oxo-octahydro-2*H*-cyclodeca[b]pyran-8-yl) acetate (2). Their structures were elucidated by detailed spectroscopic methods, including Fourier transform infrared (FTIR), mass, and nuclear magnetic resonance (NMR) experiments including 1D and 2D NMR spectroscopy. The macrocyclic pyrone derivative, (1) exhibited significantly greater antioxidant properties as determined by 2,2-diphenyl-1-picrylhydrazyl (IC50DPPH 0.65 mg $mL^{-1}$) and 2,2'-azino-bis (3-ethylbenzothiazoline-6-sulphonic acid) (IC50 $ABTS^+$ 0.73 mg $mL^{-1}$) than other studied compound (2) (IC50 > 0.75 mg $mL^{-1}$) and the commercial standard $\alpha$-tocopherol (IC50 0.65 mg $mL^{-1}$). The compound 1 exhibited greater anti-inflammatory potentials as identified by the lower IC50 for 5-lipoxygenase inhibitory assay (IC50 0.93 mg $mL^{-1}$) than 2 (IC50 0.99 mg $mL^{-1}$) and non-steroidal anti-inflammatory drug, ibuprofen (IC50 0.92 mg $mL^{-1}$). The greater electronic parameters of compound 1, along with greater hydrogen bond interactions and binding affinity justified its significant anti-inflammatory activity.

# Update on molecular identification studies of marine mammals

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Marine mammals, including cetaceans (dolphins, whales, porpoise) and sirenians (dugong) are facing growing threats from a variety of anthropogenic activities, which entail urgent need of research and education programmes to create awareness in the society for their protection and conservation. Accurate taxonomy is fundamental to conservation efforts, and imperfect taxonomy may result in lack of understanding of the population structure and genetic variability. In cetaceans, morphological features are often subtle and difficult to compare because of the rarity of specimens or widespread distributions. The number of extant species of cetaceans remains debated. Yawning gaps in our present understanding of species status and geographic variation of cetaceans would probably imply on serious taxonomic revisions. Dugong is the only complete herbivore among marine mammals and faces severe threat to its populations almost throughout the range of its distribution, calling for conservation. The present paper attempts to update the status of molecular identification of species and gender in marine mammals with special reference to Indian context.

## Current status of identification of marine mammal species

Marine mammals are identified using morphology-based approach, photo identification and molecular taxonomy. DNA sequence analysis has become a powerful tool for conservation–identifying the source of samples thought to be derived from threatened or endangered species, thus enabling to identify the species even from a small piece of tissue sample, such as skin from the marketed product. DNA Surveillance, the Web-based application assists in the identification of the species and population of unknown specimens by aligning user-submitted DNA sequences with a validated and curated data set of reference sequences. GenBank (NCBI) also has reference sequences of marine mammals though they need not necessarily be validated or curated.

## Indian efforts to study marine mammals

Ministry of Earth Sciences (MoES) funded ICAR-CMFRI to study biology, trophodynamics, fisheries interaction, contaminant accumulation, molecular taxonomy and PCR-based sex identification of marine mammals from Indian coasts. This was followed by a genetic study of Irrawaddy dolphin in Chilika Lake supported by Chilika Development Authority (CDA).

## New developments in molecular identification of marine mammals

Peer reviewed research papers and reviews on molecular identification and sex identification of marine mammals from Indian seas were published during 2001-2012. Post this period the major technical advancement in their molecular identification includes application of DNA barcoding (COI, 16S rRNA), mass spectrometry (collagen peptide mass fingerprinting) and eDNA (droplet digital PCR). Next Gen Sequencing (NGS) has been more routinely applied to modern cetacean populations recovering full mitogenomes, genomic single nucleotide polymorphisms (SNPs), or even complete nuclear genomes to develop more nuanced models of their evolutionary systematics and population histories.

Particulars of marine mammal species from Indian seas which were identified using mtDNA markers

| Sl No | Species | Location | Number of individuals (n) | mtDNA gene | Reference |
|---|---|---|---|---|---|
| 1 | *Tursiops aduncus* | Vizhinjam, Kakinada & Chennai | 5 | Cytochrome b | Jayasankar *et al.* (2008) *Zootaxa*, 1853: 57–67 |
| 2 | *Stenella longirostris* | Kakinada & Chennai | 12 | Control region & Cytochrome b | Jayasankar *et al.* (2008) *Zootaxa*, 1853: 57–67 |
| 3 | *Stenella attenuata* | Chennai | 1 | Control region & Cytochrome b | Jayasankar (2014) *Marine Biology*, NAS, India, pp. 71-99 |
| 4 | *Delphinus capensis* | Kakinada & Malpe | 3 | Cytochrome b | Jayasankar *et al.* (2008) *Zootaxa*, 1853: 57–67 |
| 5 | *Sousa chinensis* (later described as *S. plumbea*) | Gangoli & Mangalore | 2 | Control region & Cytochrome b | Jayasankar *et al.* (2008) *Zootaxa*, 1853: 57–67 |
| 6 | *Grampus griseus* | Chennai | 2 | Control region & Cytochrome b | Jayasankar (2014) *Marine Biology*, NAS, India, pp. 71-99 |
| 7 | *Neophocaena phocaenoides* | Gangoli, Malpe & Mangalore<br>Thiruvananthapuram | 7<br>1 | Control region & Cytochrome b<br>16S rRNA & COI | Jayasankar *et al.* (2008) *Zootaxa*, 1853: 57–67<br>George *et al.* (2011) *Current science*, 100(1):117-210 |
| 8 | *Physeter macrocephalus* | Chennai | 2 | Cytochrome b | Jayasankar (2014) *Marine Biology*, NAS, India, pp. 71-99 |
| 9 | *Balaenoptera musculus* | Mandapam | 1 | Control region & Cytochrome b | Jayasankar (2014) *Marine Biology*, NAS, India, pp. 71-99 |
| 10 | *Balaenoptera edeni* | Mandapam<br>Thiruvananthapuram | 1<br>1 | Control region & Cytochrome b<br>16S rRNA & COI | Jayasankar *et al.* (2007) *Indian Journal of Fisheries*, 54(3):339-343.<br>George *et al.* (2011) *Current science*, 100(1):117-210 |
| 11 | *Orcaella brevirostris* | Chilika Lake | 11 | Control region & Cytochrome b | Jayasankar *et al.* (2011) *Molecular Biology Reports*, 38:1661–1668 |
| 12 | *Dugong dugong* | Mandapam | 1 | Control region & Cytochrome b | Jayasankar (2014) *Marine Biology*, NAS, India, pp. 71-99 |

## Way forward

Molecular identification of cetaceans of Indian seas has clearly indicated the need for studying more number of species and individuals; phylogenetic relationships to understand the evolution of different species; and genetic variation vis-à-vis global geographic distribution of different species for their biodiversity conservation plans. It is essential to venture into stock assessment of these gentle giants in our seas using non-invasive techniques like eDNA analysis. This is even more important in the context of conforming to global ocean conservation efforts like US Marine Mammal Protection Act (MMPA).

# Corbiculid and Venerid clams from coastal areas of Kerala: Abundant bioresources for high-value compounds of pharmaceutical importance

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Bivalve clams were recognized as predominant seafood resources with traditional health food applications among the coastal populace of Kerala. Among the different bivalve clam species, *Villorita cyprinoides* (Corbiculid black clam) and *Paphia malabarica* (Venerid short necked yellow-foot clam) are the common resources, abundantly available in the coastal regions of Kerala. These clams were evaluated as bioresources for high-value compounds of pharmaceutical importance. The greater contents of long chain *n*-3 polyunsaturated fatty acids (> 15%), especially, eicosapentaenoic acid and docosahexaenoic acid in these species demonstrated their dietary qualities as potential functional food candidates.

Bioassay-guided chemical prospecting of *V. cyprinoides* led to the isolation of metabolites under spirocyclic ethers (1-2), irregular meroterpenoids (3-5), hexahydro-isochromenyls (6-7) and cholestenols (8-

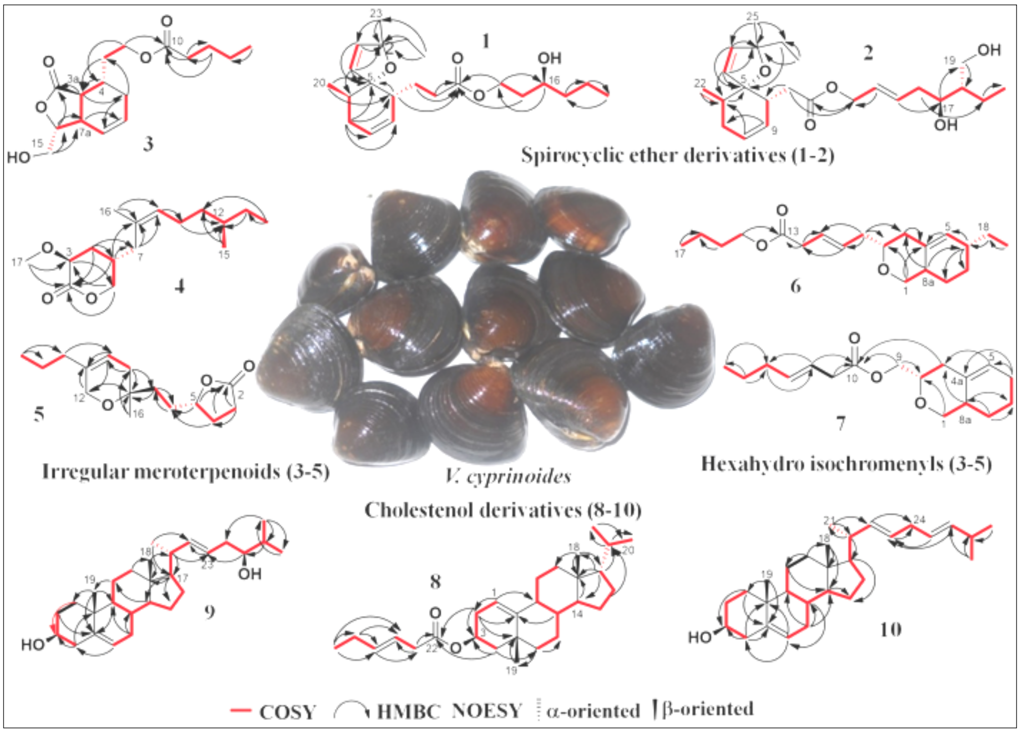


Fig. 1. [1]H-[1]H COSY, HMBC and NOESY correlations of ten biogenic secondary metabolites from *V. cyprinoides*. The key [1]H-[1]H COSY couplings have been represented by the red coloured bold face bonds. The HMBC couplings were indicated by double barbed arrow. The NOESY couplings were indicated by dashed and wedged bonds

10) categories (Figure 1). Spirocyclic ethers, 16-hydroxyhexyl-(2-ethyl-2,6-dimethyl-1-oxaspiro[4.5]dec-3,8-dien)-10-propanoate (1) and (*E*)-18-ethyl-17,19-dihydroxyhept-14-enyl-(2-ethyl-2,6-dimethyl-1-oxaspiro[4.5]dec-3,8-dien)-10-acetate (2) were enclosed rearranged monocyclofarnesyl with dihydrofuran ring spiro-fused to substituted cyclohexene, and possessed an oxaspiro[4.5]deca-dienyl skeleton. *O*-heterocyclic fused irregular meroterpenoid, 8-(1,3,3a,4,5,7a-hexahydro-1-(hydroxymethyl)-3-oxoisobenzofuran-4-yl)-ethyl-pentanoate (3) along with one each of *O*-heterocyclic pyranone/pyran, tetrahydro-3-methoxy-5-((*E*)-8,12-dimethyloct-8-enyl)-pyran-2-one (4) and dihydro-5-(8-(9,12-dihydro-8-methyl-11-propyl-2*H*-pyran-8-yl)-ethyl)-furan-2(3*H*)-one (5). Compound 3 was composed of C11 skeleton including hexahydro-oxoisobenzofuran and pentanoate. Compound 4 was found to be α-pyrone enclosed sesquiterpene-based C16-prenylated bisabolene meroterpenoid, whereas 5 enclosed an irregular C15-furano-meroterpenoid. Hexahydro-isochromenyl meroterpenoids, (10*E*)-butyl-9-(6-ethyl-hexahydro-1*H*-isochromen-3-yl)-pent-10-enoate (6) and (12*E*)-(hexahydro-1*H*-isochromen-3-yl)-methyl-hept-12-enoate (7) were identified, in which 6 was irregularly arranged C20-hexahydro-isochromenyl meroterpenoid, whereas 7 was a C17-isochromenyl meroterpenoid. The abeo-pregnane-type sterol, 19 (10→5) abeo-20-methyl-pregn-1-en-3-yl-3β-methoxy-hex-25-enoate (8) and two cholestenols, characterized as (22*E*)-$24^1$-homocholesta-5,22-dien-(3β,$24^1$β)-diol (9) and (22*E*),($24^1$*E*)-$24^1$,$24^2$-dihomo-cholesta-5,22,$24^1$-trien-3β-ol (10) were reported. Cholesta-dienol derivative, 9 was enclosed alkenes, and hydroxyls at C-17, whereas dihomocholesta-trien-ol, 10 possessed isolated alkenes at C-22 and C-$24^1$.

Spirocyclic ethers displayed greater antioxidant activities against DPPH radical (IC50 0.54-0.59 mg/mL), when equated to α-tocopherol and other compounds (IC50 > 0.60 mg/mL). The $ABTS^+$ scavenging properties of 1 and 2 (IC50 0.62-0.67 mg/mL) and 5 (IC50 0.64 mg/mL) were found to be greater than other compounds and α-tocopherol (IC50 0.76 mg/mL). The spirocyclic ether, 2 exhibited significantly greater inhibitory activity against COX-2 (cyclooxygenase-2) (IC50 0.65 mg/mL) when related to other compounds (IC50 > 0.70 mg/mL). Similarly, 1-2 (IC50 0.75-0.77 mg/mL), 3 (IC50 0.76 mg/mL) and 5 (IC50 0.80 mg/mL) were exhibited greater inhibitory potentials against 5-LOX (5-lipoxidase) as compared to other compounds and ibuprofen (IC50 > 0.90 mg/mL). The greater numbers of hydrogen bonds in the active regions of 5-LOX and COX-2 along with lower values of docking parameters were recorded for 2 and 3 in molecular docking studies. Thus, *in vitro* anti-inflammatory potentials of these compounds were deduced to be coherent with *in silico* molecular docking calculations.

Chemical investigations of *P. malabarica*

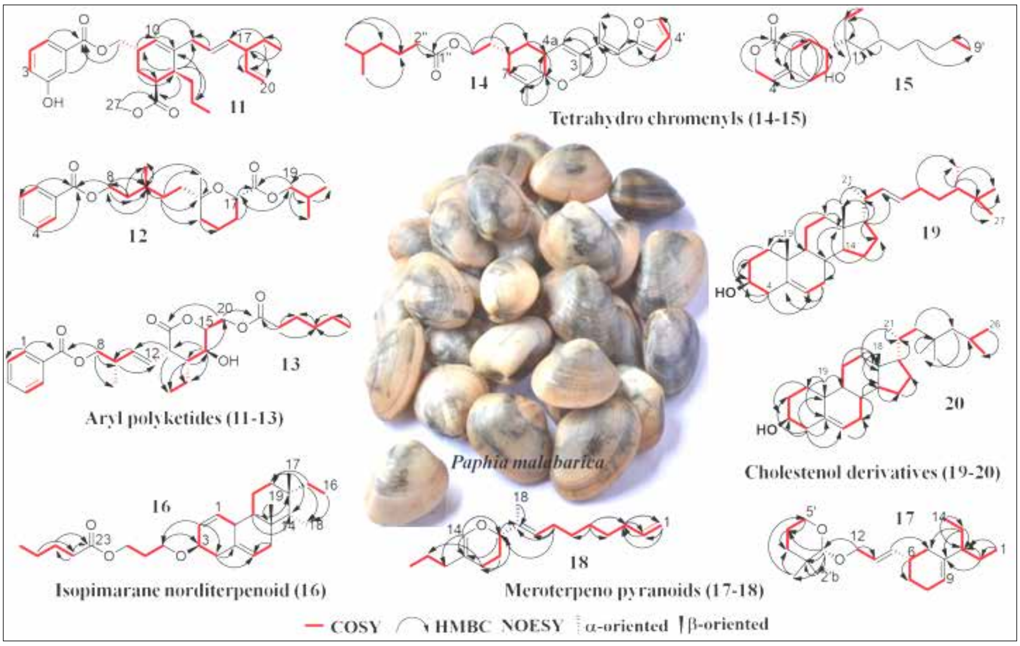


Fig. 2: $^1$H-$^1$H COSY, HMBC and NOESY correlations of ten biogenic secondary metabolites from *P. malabarica*. The key $^1$H-$^1$H COSY couplings have been represented by the red coloured bold face bonds. The HMBC couplings were indicated by double barbed arrow. The NOESY couplings were indicated by dashed and wedged bonds

were isolated metabolites belonging to aryl polyketides (11-13), tetrahydro-chromenyls (14-15), isopimarane-norditerpenoid (16), meroterpeno-2*H*-pyranoids (17-18) and cholestenols (19-20) (Figure 2). The aryl polyketides, (13-(methoxycarbonyl)-11-((*E*)-18-ethylhexa-16,19-dienyl)-12-propyl-cyclohex-10-enyl)-methyl-3-hydroxy benzoate (11), isobutyl-13-(6-(benzoyloxy)-10-methylpentyl)-tetrahydro-13-methyl-2*H*-pyran-17-carboxylate (12) and (*E*)-12-(17-ethyl-tetrahydro-16-hydroxy-15-(methylpentanoate)-14-oxo-2*H*-pyran-13-yl)-9-methyl-but-11-enyl benzoate (13) were reported. Previously undescribed tetrahydro chromenyl derivatives, $6^{1}$-(3-((*E*)-$3^{1b}$-(furan-2'-yl)-prop-$3^{1b}$-en-$3^{1}$-yl)-4a,5,6,8a-tetrahydro-8-methyl-2*H*-chromen-6-yl)-ethyl-5''-methyl-hexanoate (14) and 7-(2'-ethyl-1'-hydroxynonan-2'-yl)-6,7,8,8a-tetrahydro-3*H*-isochromen-1-(5*H*)-one (15) were composed of furanyl-2*H*-tetrahydro-chromenyl (14) and tetrahydro-isochromen-(5*H*)-one (15) moieties. The 18 (4→14),19 (4→8) bis-abeo-nor-isopimarane-1,5-diene-3-yl-3β-methoxy-propyl pentanoate (16) was found to be C19-isopimarane norditerpenoid possessing bis-abeo-C19-norditerpenoid. The C18 sesquiterpenoid with irregularly prenylated farnesene, 2-((*E*)-deca-1,8-dien-10-yl)-11,12-dihydro-13-propyl-2*H*-pyran (18) and C21 prenylated bisabolene-type meroterpenoid, 1'-((10*E*)-10-(10-(pentan-4-yl)-cyclohex-4-enyl)-allyloxy)-tetrahydro-2',2'-dimethyl-2*H*-pyran (17) were reported. Sterol derivatives, (22*E*)-$24^{1}$,$24^{2}$-methyldihomocholesta-5,22-dien-3β-ol (19) and 23-*gem*-dimethyl cholesta-5-en-3β-ol (20) were possessing C-30 dihomosterol and 23-*gem*-dimethyl-3β-hydroxy-$\Delta^{5}$-cholestane frameworks, respectively.

The aryl polyketide (13) and furano-chromenyl (14) were exhibited greater DPPH (IC50 ~0.57 mg/mL) and $ABTS^{+}$ (IC50 ~0.68 mg/mL) scavenging activities as compared to other compounds in the series and α-tocopherol (IC50 > 0.65 mg/mL). The hydroxy benzoate derivative, 13 (IC50 0.68 mg/mL) was registered greater inhibitory potential against COX-2 followed by 11 (IC50 0.74 mg/mL) and 4 (IC50 0.72 mg/mL). Potent 5-LOX inhibitory effects were recorded for 13, 16 and 14 (IC50 ~0.76 mg/mL), when related to other compounds and ibuprofen (IC50 > 0.80 mg/mL). Moreover, greater number of hydrogen bonds (5-LOX/COX-2 active regions), and lesser docking parameters of 11-13 and 16 were found to be linear with their greater *in vitro* anti-5-LOX/anti-COX-2 potentials.

The coastal waters of Kerala are acknowledged for their particular richness of innumerable bivalve clams. The present study described the two prominent bivalve clam species, *V. cyprinoides* and *P. malabarica* as valuable biosources for potentially useful pharmacological properties against various inflammatory mediators and reactive oxygen species. Furthermore, the reported bioactives from the bivalve clams will form abundant resources for the development of high-value compounds of pharmaceutical importance.

# Pharmacological properties of selected brown and red macroalgae from the Indian coast

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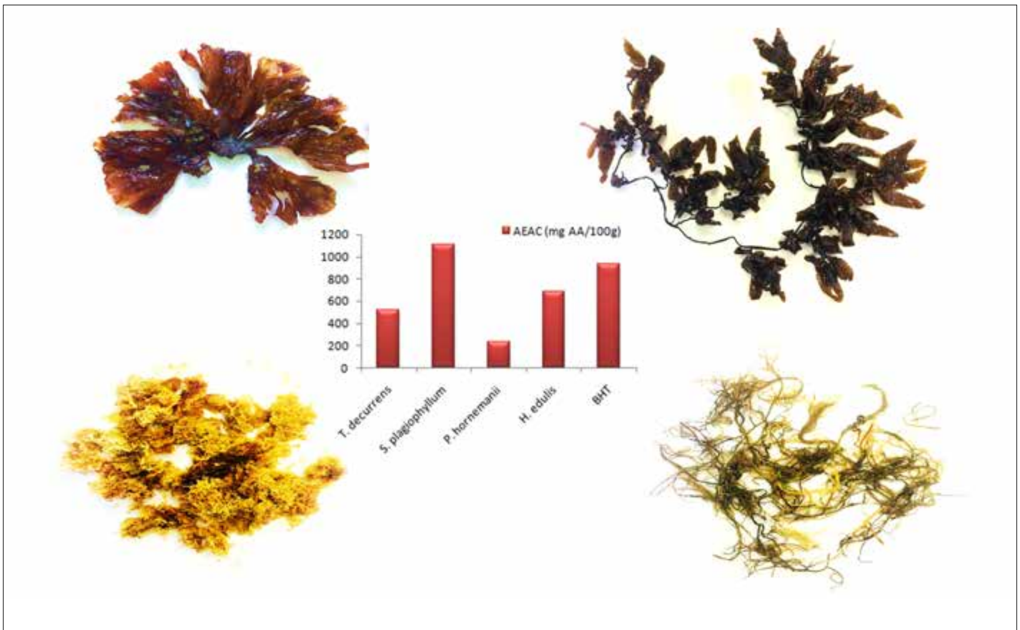
Recently, the demand for a clean tag on food supplements led to the inclusion of bioactive compounds from marine macroalgae as natural ingredients. Its immense potential as active pharmacological constituents is often left unexplored. Numerous macroalgae are edible and possess remarkable active compounds such as phlorotannins, polysaccharides, pigments, terpenes, alkaloids and poly unsaturated fatty acids which are highly potential against life style diseases like diabetes, cardiovascular diseases, tumor and hypertension (Jacobsen *et al*., 2019). Moreover, these rich sources of natural products have found its utilization in nutraceuticals and cosmetics also (Wijesekara *et al*., 2011). This study focuses on the Ethylacetate:Methanol crude extracts of four brown (*Lobophora variegata*, *Turbinaria decurrens*, *Stoechospermum marginatum*, *Sargassum plagiophyllum*) and four red (*Gracilaria corticata*, *Portieria hornemannii*, *Acanthophora spicifera*, *Hydropuntia edulis*) macro-algal species belonging to the subclasses Dictyotophycidae, Fucophycidae and Rhodymeniophycidae collected from South East Coast of India and its bioactivities were verified using different *in vitro* assays. The crude extracts of brown algae *T. decurrens*, *S. plagiophyllum* and red algae *H. edulis* showed significant 2, 2-diphenyl-1-picryl-hydrazil (IC50 = 0.58, 0.27, 0.82 mg/mL), 2,2-azino-bis-3-ethylbenzothiozoline-6-sulfonic acid (IC50




Graphical abstract representing the images of active macroalgae and antioxidant activity of selected macroalgae in terms of AEAC (ascorbic acid equivalent capacity).

= 0.2, 0.3, 0.44 mg/mL) radical scavenging activities, α-amylase (IC50 = 0.52, 0.82, 0.45 mg/mL) and β-glucosidase (0.53, 0.41, 0.42 mg/mL) inhibition activities respectively than displayed by other species. Red algae *H. edulis* (IC50 = 0.40 mg/mL) and brown algae *L. variegata* (IC50 = 0.52 mg/mL) were effective in inhibiting pro-inflammatory 5-lipoxygenase enzyme. The antibacterial activity of the Ethylacetate:Methanol extracts of macroalgae were estimated against four microorganisms. Significant correlation studies between total phenolic contents, antioxidant, anti-diabetic activities and electronegative functionalities were underlined. The high content of phenolic constituents in the macroalgae has considerably contributed to its anti-oxidant activity. This study has demonstrated marine macroalgae crude extract as pharmaceutically active treasure trove, hence its further utilization in nutraceuticals and drug industries.

# Bioactivities of carotenoids from Thraustochytrids protist

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Marine microorganisms are a natural source for a variety of drugs for pharmaceutical, food and cosmetic applications such as carotenoids among others. Current research on potential bioactivities of these compounds indicate that these can play key roles in prevention (and even treatment) of several health conditions, e.g. cancer, cardiovascular problems, atherosclerosis, rheumatoid arthritis, muscular dystrophy, cataracts and some neurological disorders. The intrinsic antioxidant and anti-bacterial features of these compounds are the principles behind such positive biological activities. Thus we aimed to screen the carotenoid production potential of Thraustochytrid protists and evaluation of their antibacterial and antioxidant activities using different *in vitro* assays. Quantification of total carotenoids showed that all the Thraustochytrid strains we studied could produce carotenoids and concentration of total carotenoid range from 0.958 to 2.3µg/g. Carotenoid content was highest in the strain Kanv (2.33µg/g). Identification of carotenoid by TLC showed that all the strains except JML5 and JMVL7 displayed 5 pigments with RF values of 0.99, 0.87, 0.75, 0.4 and 0.25 representing the pigments β. Carotene, Echinone, Astaxanthin diester, Canthaxanthin and Leutin respectively. The MIC and MBC result of the carotenoid revealed that sensitivity was observed between 15.6 µg/mL to 125 µg/mL against all the tested bacterial pathogens. Antioxidant activity was assessed by DPPH, ABTS and FICA method showed a good activity with Ic50 value of 102.84mg/mL, 11.16mg/mL and 102.82mg/mL respectively.

# Ulcerative Dermatitis in Asian Seabass *Lates calcarifer* (Bloch, 1790) from the growout sea cages at Thoothukudi coast of India

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Seven thousand and eight hundred fingerlings of the Asian sea bass, *Lates calcarifer* (Bloch, 1790) (Avg. size of 6.0 cm) were transported from the RGCA, Sirkali and stocked in 20 happa (size 2m x 2m x 2m) in the two selected sites in coastal fishing villages of Sippikulam (Lat 8°51'21.8724" N; Long 78°14'59.2065" E) and Keelavaipar (Lat.8°59'46.1946"N; Long.78°15'28.5548"E). The fingerlings were stocked at a density of 45 fishes/m$^3$/happa. Two happa were tied in the inner net of each sea cage (10 numbers were fabricated with Galvanized Iron (GI) of 6 m dia. with 2.5 m depth) and reared for a period of 30 days. The fingerlings were fed *ad libitum* with chopped fish flesh twice a day. The grown fingerlings (Avg. size of 12 cm) were uniformly stocked (10 fingerlings/m$^3$) during the month of January 2018 and fortnightly sampling for growth was carried out. After 70 days of grow-out culture, sudden mortality of 72 numbers of fingerlings (110±20g) was noticed in two cages. On clinical examination, the infected fishes exhibit erratic swimming and inappetence. The gross lesions revealed eroded fins, skin ulceration and haemorrhages, reddening eye, exoptholmosis, deep red spleen and pale liver. Sterile swabs from ulcerated skin and kidney samples were taken for bacterial isolation. The infected organs (gill, liver & spleen) were fixed in 10% Neutral buffered formalin (NBF) for histological observations.

Histologically, the liver showed fatty changes and congestion, spleen revealed degeneration and hyperaemic changes whereas secondary gill lamellae showed erosion and necrosis. Based on the phenotypic and cultural characteristics, Gram-positive cocci, *Streptococci* sp. and Gram-negative bacilli, *Shewanella* sp. were identified from the kidney and ulcerated skin respectively. *Shewanella* species is a non-fermentative, motile bacilli with a single polar flagellum. The isolated bacteria exhibited mucoid colonies with haemolysis on blood agar. Based on the 16srRNA sequencing, the isolate from the skin was confirmed as *Shewanella algae*. The study indicated that the uncommon co-infection of the two opportunistic bacteria, *Streptococci* sp. and *Shewanella algae* isolated from the kidney and ulcerated skin respectively, caused 4.6% mortality in cage cultured sea bass.

Initially, the infected cages were isolated and moved towards deeper sites followed by an exchange of inner cage-net with suitable mesh size. The infected fishes were fed with one gram oxytetracyclin in one kilogram chopped fish flesh by mixing with the regular feed for five days continuously. After the treatment period, the infected fishes recovered and further mortality was not observed. For better health management, it is also suggested to provide immunostimulants and mineral mixture (watermin forte) weekly twice for 2 months during the initial grow-out period.

# Molecular cloning and characterization of glycogen phosphorylase gene from *Crassostrea madrasensis*: A molecular marker for regulation of glycogen metabolism and thermal stress in oysters

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Glycogen is the primary source of glucose reserve in marine molluscs and plays a central role in providing energy for maintenance, during thermal stress and gametogenic development. Glycogen phosphorylase is a homodimeric or tetrameric enzyme that removes glucose residues from (1-4) linkages within glycogen molecules to produce glucose-1-phosphate and enters glycogenolysis. Covalent modifications through phosphorylation of phosphorylase-b to phosphorylase-a greatly enhances its glycogen breakdown activity as an immediate adaptation to thermal stress in mussels. Seasonal variation in glycogen storage in adult oysters correlates with the annual reproductive cycles; however, not explained by changes in the concentration of extracellular glucose. Hence, studying the expression profile of glycogen phophorylase gene at different seasons and conditions clearly elucidates the glycogen metabolism. Thus, glycogen phophorylase gene is a useful molecular marker in studying the regulation of glycogen metabolism, thermal stress and reproduction in oysters. Scanty information is available on the structural and functional properties of glycogen phosphorylase genes in oysters and the information is lacking in *Crassostrea madrasensis.*

Indian backwater oyster, *C. madrasensis* samples were collected from Ernakulam district of Kerala, India and tissue sample was collected for RNA isolation using Trizol reagent as per manufacturers protocol and converted into cDNA. The primers for glycogen phosphorylase were designed from closely related oysters and mussels from conserved regions. The polymerase chain reaction (PCR) reaction was performed with forward and reverse primers. The PCR amplification was performed with the initial denaturation at 94 °C for 3 min followed by 35 cycles at 94 °C for 40 sec, 56 °C for 40 sec, 72 °C for 60 sec and a final extension step at 72 °C for 7 min. The PCR products were run on 1.5% agarose gels and bands obtained in the gel were cut and DNA eluted using quick gel extraction kit. Molecular cloning of glycogen phosphorylase gene was done using the vector PTZ57R/T and the ligated product was transformed into DH5$\alpha$ strain of *E. coli*. Blue-white colony selection was performed to select the positive clones and colony PCR performed for identification and confirmation of colonies with inserts. The colonies that showed the presence of phosphorylase gene were selected for plasmid isolation and the cloned products were sequenced. The sequence was analyzed using BLAST software in the NCBI GenBank nucleotide database for finding homology with other sequences. Ten sequences were taken for multiple sequence alignment using ClustalW software and phylogenetic tree was constructed using MEGA 7 software. Generunner software was used to translate the sequence into protein sequence to analyse the aminoacid sequence for the presence of functional domains that are specific to glycogen phosphorylase gene. The sequence details were prepared using Sequin Version

15.10 software, submitted to NCBI and obtained GenBank Accession number MF537213.

*C. madrasensis* partial glycogen phosphorylase gene (760 bp) showed maximum homology (94%) with *Crassostrea gigas* glycogen phosphorylase gene, followed by 93% with *C. angulata*, and 77% with *Sturnus volgaris*. The deduced amino acid sequence of glycogen phosphorylase gene indicates the putative N-glycosylation sites and putative protein kinase phosphorylation sites and depicted in the Figure. Neighbor-Joining method of phylogentic tree analysis showed that *C. madrasensis* glycogen phosphorylase gene shared the same cluster as those of the *C. gigas* and *C. angulata*. As they belong to same family and genus, they are closely related and shared the same cluster and exhibits maximum homology than other groups in the tree. The divergence analysis revealed that *C. madrasensis* has a maximum of 45% genetic difference with red bellied piranha, *Pygocentrus nattereri* and the lowest difference of 7% was noticed with *C. gigas* and *C. angulata*.

# Isolation, sequencing and partial characterization of insulin like growth factor gene from Pompano, *Trachinotus blochii*

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Finfish mariculture is gaining momentum in India and one of the candidate species successfully farmed is the Silver Pompano *Trachinotus blochii.* Studying the functional genomic aspects which regulate growth and other physiological parameters is essential for the sustainable practice of finfish culture. Insulin like growth factor (IGF) is reported to be involved in the regulation of proteins, lipids, carbohydrates, mineral metabolism in the cells, cell differentiation and proliferation, and ultimately in body growth of cultured fishes.

The study elucidated the structure of the IGF, an important functional gene, from cultured pompano, *Trachinotus blochii.* The PCR amplifications were carried out using the cross amplification strategy with primers reported from Gilt-head sea bream, *Sparus aurata*. The attempts became successful with modifications in the PCR parameters and resulted in two amplicons with 900bp and 1500bp respectively. The PCR products free from non-specific amplifications were eluted and sequenced. The edited sequences obtained were subjected to similarity search in NCBI-BLAST. The sequences obtained were found to be covering promoter region (861 bp) through first exon (25bp) with the first fragment amplified and the second fragment was covering the full first intron (1466bp).

Preliminary analysis shows that, the gene structure is 87% and 80 % similar with *Dicentrarchus labrax* insulin growth factor gene 1 and 2 respectively, as reported in sea bream. Screening of more samples for gene specific SNPs linked to traits of culture importance would be promising as the study serves as the pilot one, for the first time in the candidate species, which opens up scope for further research.

# Identification and molecular characterization of two ring-between ring (RBR) genes from Asian Seabass (*Lates calcarifer*)

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Post-translational modifications like ubiquitination play a major role in immune regulation. RBR is an E3 ubiquitin ligase in mammals that have antiviral activity and are involved in regulation of the cell cycle and apoptosis. RNF family proteins are evolutionarily conserved in higher eukaryotes. The present study focuses on the cloning and molecular characterization of two RBR genes-RNF144 and RNF144a homologue in *Lates calcarifer*. The full-length cDNA of *Lates* RNF144 (*Lc*RNF144) contain an ORF of 684 bp coding for 227 amino acids and *Lc*RNF144a contain an ORF of 888 bp coding for 295 amino-acids. RNF 144 have a predicted molecular mass of 25.2 kDa and a theoretical pI of 5.71 were as RBR144a have predicted molecular mass of 33.2 kDa and theoretical pI of 5.47. Structurally, *Lc*RNF144 and *Lc* RNF144a contains RING, in-between-ring (IBR) and transmembrane (TM) domains. Amino acid sequence analysis of these domains reveals the strict conservation of the key residues like cysteine and histidine. Phylogenetic analysis reveals that both the genes share more similarity with other teleost counterparts. The detailed study of RBR genes gives more insight into antiviral response in fish.

# Isolation and characterization of chitin from deep sea mud shrimp (*Solenocera hextii*) using FTIR spectroscopy

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Chitin is a biopolysaccharide, occurring in nature as ordered crystalline microfibrils and forming structural component in a wide number of marine invertebrates, crustacean shells, insect cuticle, and cell wall of fungi and yeast. The main commercial sources of chitin are crab and shrimp shells which are the major organic waste products from the seafood processing industry and pose environmental concerns. *Solenocera hextii,* commonly known as deep sea mud shrimp is one of the prominent deep sea shrimp exported from India. It is landed across the east and west coasts of India. Chitin occurs naturally in three polymorphic forms $\alpha$, $\beta$ and $\gamma$-chitin. The present investigation was aimed at isolating chitin using a chemical method. The shrimp shell wastes were washed thoroughly with distilled water and subjected to alkaline treatment to solubilize proteins and acid treatment to dissolve calcium carbonate. Yield, Moisture, Nitrogen and Ash contents of the extracted chitin were determined. FTIR analysis was used to identify the forms of chitin and its degree of acetylation. In FTIR spectra, the isolated chitin using chemical method recorded two absorptions in the Amide I region at 1659 and 1626 $cm^{-1}$. The results confirm that the chemical method adopted in the present investigation converted the shell waste to $\alpha$ chitin. The yield of chitin from wet shell was found to be 3%. The chitin thus obtained can be employed for preparing chitosan for various applications and the species *S. hextii* can be used as a good source of raw material for the extraction of chitin in commercial scale.

# Bioprospecting industrially important biomolecules from gut microflora of *Scylla serrata*

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The gut of an organism acts as a natural habitat for bacteria that are either beneficiary or harmful to the organism. As the role of the gut is the uptake of nutrients and water, the beneficiary microflora may produce enzymes which aid the host's digestive processes. *Scylla serrata* (mud crab) is a common inhabitant of estuarine waters. They are mainly carnivorous in nature but juvenile forms are known to feed on plankton and plant material. These crabs are also highly cannibalistic in nature where larger crabs feed on smaller crabs that have just undergone moulting. Since the species has a wide range of feeding habitats, the gut microflora was presumed to produce a variety of enzymes.

A live male mud crab was procured from Malim Jetty, Panjim in Goa, India. The gut of the crab was dissected and homogenized in PBS buffer. The homogenate was plated onto Zobell Marine Agar and Nutrient Agar plates. Eight isolates designated as FGN1, FGN2, MGN4, HGN1, HGN2, MGZ2, HGZ1, HGZ2, were isolated from the gut of the crab (FG: Fore Gut, MG: Mid Gut, HG: Hind Gut). These isolates were screened for the production of enzymes such as amylase, chitinase, cellulase and ligninase. They were also screened for the production of exopolysaccharide, luminiscence and CaCO3 solubilisation. Among the eight isolates, six showed positive results for at least one enzyme. One isolate, MGN4 showed positive results for production of all four enzymes. Five isolates showed positive exopolysaccharide production and only MGN4 showed positive CaCO3 solubilisation. However none of the eight isolates were found to exhibit bioluminescence. Apart from producing hydrolytic enzymes, the isolate MGN4 exhibited degradation of methylene blue which served as a substitute for lignin. Consequently, MGN4 can be used for biotechnological applications in dye degradation and remediation of contaminated waters. Therefore it was selected for further investigations. Biochemical and morphological testing revealed it to be of the *Macrococcus* genera. Molecular characterization using 16s rRNA gene sequencing established the isolate to be *Macrococcus caseolyticus.* SEM imaging confirmed the morphological structure and suspected biofilm production.

In conclusion it can be said that the bacterial flora isolated from the gut of wild mud crab, *Scylla serrata* showed immense potential for a wide range of biotechnological applications and needs to be utilized as a resource.

# A comparative analysis of omega-3 fatty acid productivity in three marine diatoms

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Diatoms (Bacillariophyceae) are the largest diversified group of phytoplankton. They can thrive in various environmental conditions and greatly contribute to primary biomass production. Moreover, they are also considered as primary source of omega-3 fatty acids. Two *Thalassiosira* species (*T. lundiana* CSIRCSMCRI 001 and *T. andamanica* CSIRCSMCRI 002) and one *Chaetoceros curvisetus* CSIRCSMCRI 003 species were isolated from sea coasts of Gujarat and axenic cultures were developed under laboratory conditions. Each axenic culture was individually grown in 3 L flask containing 1 L f/2 media. Each inoculum was incubated for 15 days at constant 12 h light (100 $\mu mol^{-1} cm^{-1}$) and temperature (25±2°C). After the incubation period, biomass was harvested, and the free unsaturated fatty acids were profiled using GC-TQMS using standard protocols. TheGC-TQMS chromatograms revealed that omega-3 fatty acids including $\alpha$-linolenic acid (ALA), eicosatetraenoic acid (ETE), eicosapentaenoic acid (EPA), docosapentaenoic acid (DPA) and docosahexaenoic acid (DHA) in total was highest (25%) in *T. andamanica* CSIRCSMCRI 002 followed by *T. lundiana* (22%) and *C. curvisetus* (16%). Omega-3 are essential fatty acids. The cultures of *T. andamanica*, *T. lundiana* and *C. curvisetus* can be used as a direct feedstock in aquaculture. Furthermore, these extracted omega-3 fatty acids may be recommended in pharmaceutical application as a dietary supplement due to their neuro-protective and neuro-regenerative roles in the human brain.

# Electron microscopic, ICP-MS, FT-IR and fatty acid analysis of nidamental gland and accessory nidamental gland of *Sepia pharaonis*, cephalopod-mollusc

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Cephalopods lay their eggs in cultches and they take weeks or months to develop before hatching. This long term protection is provided by the specialized accessory reproductive organ called nidamental gland complex (NGC) which consists of main nidamental gland (NG) and accessory nidamental gland (ANG). Nidamental gland secretes jelly coat whereas accessory nidamental gland secretes antimicrobial compounds to protect the eggs from pathogens. The combined action of these glands are involved in the protection of eggs for years together. The present study was carried out to investigate the presence of functional groups, elements (macroelements, microelements and metals) and fatty acid profiles of nidamental and accessory nidamental glands of *Sepia pharaonis*. The ultrastructure of the nidamental gland complex was studied using TEM. In the present study, the macro elements present in the nidamental gland were sodium (Na) and potassium (K). The microelements were zinc (Zn), copper (Cu), boron (B), manganese (Mn), chromium (Cr) and selenium (Se). The metals found in the nidamental gland were Arsenic (As), aluminium (Al), strontium (Sr), nickel (Ni), mercury (Hg) and lead (pb). Among these elements, most were proved to have potent antimicrobial activity. The presence of these essential elements may either directly help in egg protection by possessing antimicrobial activity or involving as a cofactor in the synthesis of antimicrobial compounds by the nidamental gland complex. The results of spectrochemical analysis indicate the presence of functional groups such as amines, phenols, ketones, alkenes, alcohol, carboxylic groups and halo groups. All the three types of fatty acids such as saturated fatty acids, monounsaturated fatty acid and polyunsaturated fatty acids were present. The saturated fatty acids found in the nidamental gland were undecanoic acid (C11:0–3.84%), stearic acid (C18:0–2.76%), arachidic acid (C20:0–13.55%), palmitic acid (C16:0–9.52%), lauric acid (C12:0–9.13%), pentadecanoic acid (C15:0–7.75%) with the percentage of 47.86% of the total fatty acids. MUFA found in the nidamental gland were margaroleic acid (C17:1–16.64%), trans-Elaidic acid (C18:1–4.71%), myristoleic acid (C14:1–2.24%), margaric acid (C17:0–1.31%) and cis-10 pentadecanoic acid (C15:1–1.10%) composed of 24.69% of total fatty acids. PUFA found in the nidamental gland was Eicosapentaenoic acid (C20:5–27.43%) having the percentage of 27.43% of the total fatty acids. The study is aimed to understand the role of these elements and fatty acids in embryo protection coat

# Phylogeographic evidence of stock structure in the epipelagic Indo-Pacific king mackerel *Scomberomorus guttatus*

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The spotted seer *Scomberomorus guttatus* (Bloch & Schneider, 1801) (Perciformes: Scombridae) is a premium table fish having a wide distribution in the Indo-Pacific from Persian Gulf to the Sea of Japan. The species is encountered mostly in neretic waters and is believed to be less migratory compared to *Scomberomorus commerson*. It contributes to 4.7% of all India scombrid fisheries and is abundant only in the north-west (Gujarat and Maharashtra) and East coasts (West Bengal, Odisha, Andhra Pradesh and Tamil Nadu). The biology and stock assessment of the species has been well documented from India with little focus on its genetic diversity. We used the 600 bp region of Cytochrome c oxidase subunit I gene for phylogeographic analysis of *S. guttatus*; individuals from India (Odisha, Andhra Pradesh, Calicut, Mumbai and Veraval) together with sequence datasets available in NCBI GenBank from areas of its known distribution were used. The analysis revealed two robustly supported clades, the Bay of Bengal + Western Pacific Ocean Clade and the Arabian Sea Clade with a significant genetic divergence of 2.42%, signalling a strong genetic population division. Further investigations with more molecular markers and truss morphometry is under progress to ascertain if they are cryptic sister taxa of a species complex or genetically diverged populations resultant of restricted gene flow. The output will be useful in formulating appropriate management strategies for sustainable harvesting of the globally distributed spotted seer fish.

Theme-5 Marine biotechnology and bio-marine products
(disease detection, surveillance and control)

# Development of a novel larval functional feed using bioactive microbial product by fermentation technology and its application in aquaculture

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Development of functional feeds is considered as a new opportunity in aquaculture industry where diets are formulated to achieve specific functions. The present study deals with the preparation of a functional micro feed against bacterial infections (antagonistic) for use in larviculture, by incorporating a microbial product (MP) from an antagonistic *Pseudomonas aeruginosa* MBTDCMFRI Ps04. . In this study, the fermentation technology conditions were optimized for pilot scale production of antagonistic compound using nutrient broth supplemented with 50% sea water (SW) achieved at aeration 0.5 LPM (litres per minute), agitation 100 rpm, inoculum size of 4%, pH–7.5 ± 0.2, 31$^{o}$C at 96 h in a New Brunswick BioFlo/ CelliGen 115 Fermentor. The attenuated, scaled up cultured broth was spray dried (*Pseudomonas* Microbial Product–PMP) and the minimum inhibitory concentration of PMP was determined as 781 μg/ml to inhibit $10^5$ CFU/ml of *V. harveyi* 101. Cytotoxicity assay was carried out on *Cyprinus carpio* (Koi carp) fibroblast cell lines and was found to be non–toxic to fish cell lines up to 0.2%. Lipid levels found in commercial larval feeds) was formulated by incorporating PMP at the rate of 0.2%. The homogenous blend of nutritional raw material along with PMP was extruded in a laboratory model extruder (Basic Technologies Pvt. Ltd., Kolkata), dried and further granulated into desired micro size (60–80 μm, 100–120 μm and 200–220 μm). The feeds were colour coded with different natural oleoresins to differentiate the micron sizes. A 25 days feeding trial was conducted to evaluate the effect of the newly developed micro feed and its suitability as a larval feed using the Indian white shrimp, *Penaeus indicus* larvae as a model organism at Azhikode hatchery (Dept. of Fisheries, Kerala). There were four treatments, in which the first group was fed with newly formulated PMP feed, second group with commercially available feed, third group with formulated PMP feed along with microalgae (*Chaetoceros* sp.) and the fourth group was fed commercially available feed with microalgae (*Chaetoceros* sp.). All experiments were carried out in triplicate. Growth and survival of the PMP feed was found to be superior compared to the control feed (CSF). Co-feeding was found to be more effective especially in zoea and mysis stages than feed alone. From this study, a novel, micro functional feed formulated using spray drying technology positively impacts the larval survival and growth, enhancing productivity in the hatchery phase. Our results support co-feeding of live feed along with formulated PMP feed for the early stages of the larvae. Further, it helps in the partial replacement of live feed in the hatchery. It helps to develop cost-effective shrimp hatchery feeding regimes and substitutes highly priced imported feeds.

# Biocatalytic potential of algicolous endophytes with special reference to asparaginase activity

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Endophytes, an integral part of the plant microbiome, are mainly fungi that reside within intercellular tissues of plants without triggering any disease symptoms. The absorptive mode of nutrition in fungi enables them to secrete an array of enzymes that catabolize complex organic polymers in the environment to smaller constituents. Like other microbial invasion, endosymbionts produce extracellular hydrolases as a resistance mechanism to overpower the immune response of host or to utilize host nutrients for survival. Keeping this in mind, we screened around 133 endophytes obtained from ten macroalgae viz., *Sargassum wightii, Ulva fasciata, Caulerpa peltata, Hypnea musiformis, Halymenia venusta, Enteromorpha compressa, Gratelopia lithophila, Padina tetrastomatica, Chaetomorpha antennina* and *Dictyota* sp. of Kerala Coast for their catalytic potential. Screening was done for a total of ten enzymes viz., cellulase, amylase, lipase, ligninase, gelatinase, tyrosinase, laccase, chitinase, asparaginase and glutaminase by plate assay method. Out of the 133 isolates screened, 123 expressed asparaginase activity (92.5%). More than 60% of the isolates exhibited amylase (89.5%), lipase (88%), gelatinase (78.9%) and glutaminase (69.2%) activity. Around 37.6% fungal isolates utilized cellulose substrate. Laccase (15%), chitinase (13.5%) and ligninase (12.8%) activity was comparatively low. Only 7.5% isolates displayed tyrosinase production. While comparing algae wise enzyme production, the inhabitants of brown, red and green algae exhibited maximum activity for the enzyme, anticancer asparaginase. Quantitative estimation of asparaginase production in Czapek Dox medium by potent strains revealed that *Penicillium chrysogenum* of *S. whitii* exhibited maximum asparaginase production (425.1 IU/ml) followed by *Daldinia eschscholtzii* (317.1 IU/ml) and *Fusarium equiseti* (259.2 IU/ml). Even though both asparaginase and glutaminase express anticancer property, due to some allergic responses and anaphylaxis in the patients due to glutaminase associated activity, glutaminase free asaraginases are preferred for anticancer treatments. Because of its inability to produce glutaminase, *P. chrysogenum* could be a reliable candidate to explore in cancer therapy.

# Genotyping by double digested restriction site associated dna sequencing (ddRAD Seq) in Indian oil sardine, *Sardinella longiceps* for population genomic structure analysis

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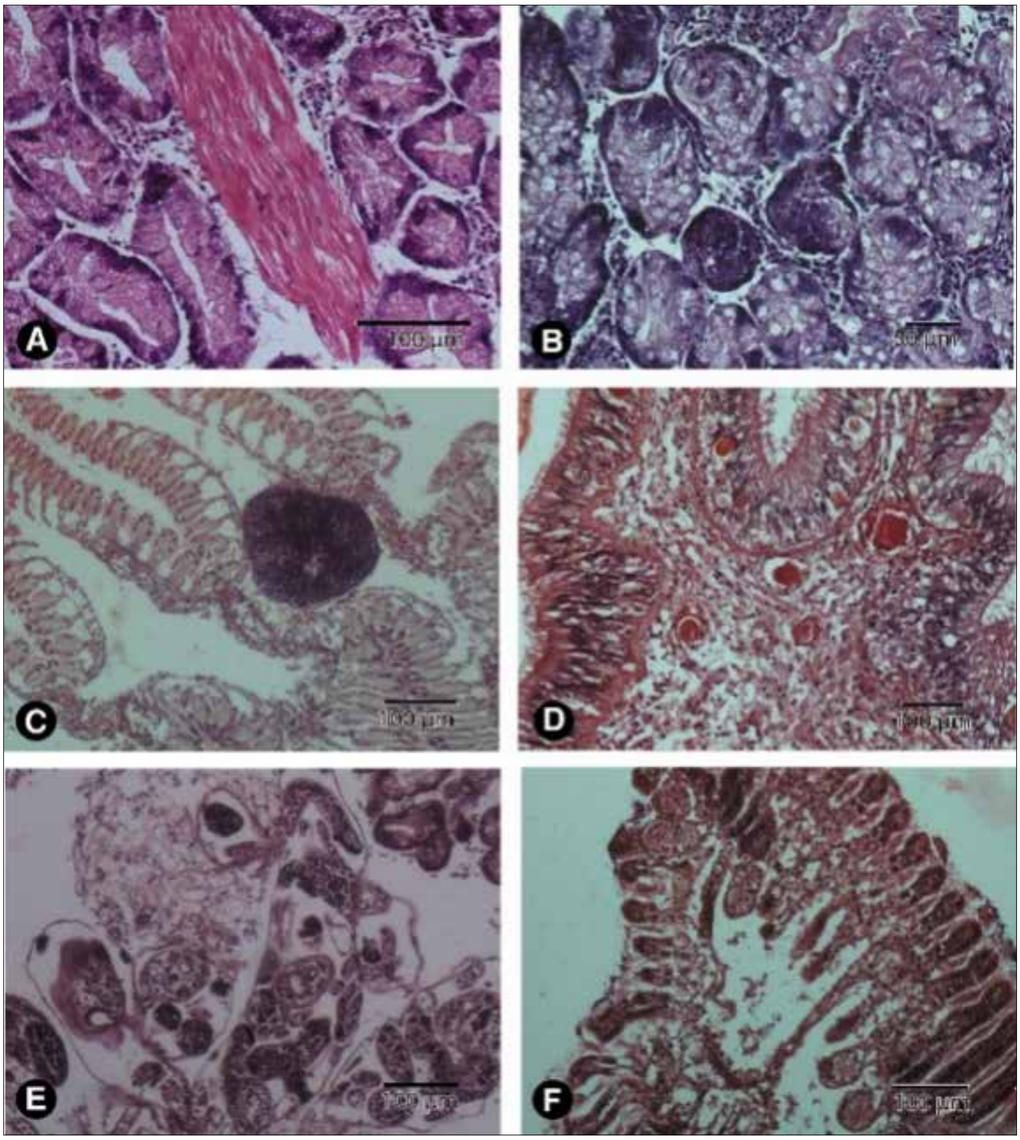
Double digested restriction site-associated DNA sequencing is a powerful tool for generating genome-wide single nucleotide polymorphism (SNPs) markers for non-model organisms. It has been used in non-model organisms for elucidating fine-scale population structure and understanding patterns of selection. In this study, we performed population genomic analysis based on ddRAD data of *Sardinella longiceps* distributed in the Indian Ocean, for identifying population genetic structure and adaptive divergence in the heterogeneous oceanic environmental.

DNA samples with high quality and quantity were selected for ddRAD sequencing (from Oman Sea, North East Arabian Sea (NAS), South-East Arabian Sea (SEAS), South West Bay of Bengal (SBOB) and North West Bay of Bengal (NBOB). The ddRAD libraries were prepared based on the previously published protocol (double-digested with *MspI* and *EcoRI* restriction enzymes). Population genetic statistics (allele frequencies, percentage of polymorphic loci, nucleotide diversity, Wright's F-statistics (FIS and FST) were computed using 'population' program in STACKS V 1.40. A neighbour-joining method, Neighbor (from Phylip programs) was used to generate a phylogenetic tree using average pairwise Fst values as input.

50076.00 polymorphic RAD loci, with 1SNP and 2 alleles were retained from the 100 samples sequenced, after de novo processing. The number of polymorphic loci genotyped is 49361.00 and among that 48473.00 loci were genotyped by at least 50% of individuals. The average frequency of major alleles (P), ranged from 0.998-0.999 and average observed heterozygosity (Ob Het) ranged from 0.0017 to 0.0020. The population of Oman Sea and NAS showed a reduced level of genetic diversity when compared to other populations.

The pairwise comparison of genetic differentiation (FST and RST) found that the Oman Sea population was highly differentiated from all other populations, with very high significance. The frequency distribution of FIS values across loci within each population indicates that SEAS has a fraction of loci with FIS value > 0.

The Delta K approach in structure analysis showed that K = 2 is the best fit model for the data and the plot of posterior probability clearly showed these two groups (Oman sea and Indian Ocean group–NEAS, SEAS, SBOB and NBOB). The loci identified as outliers (FIS > 0) may be the representation of genomic regions of local adaptation, isolated genomic regions of divergence with gene flow and genomic regions of speciation in *S. longiceps*. Thus these signals of cryptic structuring/assortative mating can be used as a starting point for more detailed study to identify the genomic region of genetic divergence in *S. longiceps* and Clupeoids. Reanalysis of the RADseq data with a reference genome based method is necessary for identifying genome-wide distribution/chromosomal regions of genetic divergence.



Microphotographs of histological alterations in the digestive diverticula and gill of clams stained with H&E: (A) Fibroma in intertubular connective tissue of digestive diverticula of the clam, *Villorita cyprinoides* from zone 2. (B) Necrotic and vacuolated tubules with numerous haemocytes infiltrating the inter-tubular tissue of the digestive gland of clam, Villorita cyprinoides from zone 2. (C) A haemocytic nodule in the gill of clam, *Paphia malabarica* from zone 3. (D) Infestation with Apicomplexa-like organism in the digestive gland of clam, *Paphia malabarica* from zone 3. (E) Trematode infection in the digestive gland of clam from zone 3: sporocyst with germ-balls and cercariae. (F) *Villorita cyprinoides* from zone 1 infested with Nematopsis like protozoa showing Oocysts in the gill tissue.

# Development of histopathological indicators in bivalve clams along the Kerala coast for assessing environmental quality

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Bivalves have been frequently used as indicators of environmental quality and their histopathology has become an imperative tool in aquatic bio-monitoring. Present study was undertaken to provide an insight into the histological alterations in the gills and digestive diverticula of the most economically important clam species of Kerala, *Villorita cyprinoides* (black clam) and *Paphia malabarica* (yellow clam) collected from three distinct sites lying parallel to the Arabian Sea: Ashtamudi Lake, Kollam (zone3), Vembanad Lake, Alappuzha (zone2) and Karumallor river, a tributary of Periyar, Aluva (zone1). Approximately 40 adult individuals from each zone were collected during the period November 2018 to June 2019 and processed as per routine histological techniques. A maximum of twenty histological lesions/alterations in the gills and digestive glands were evaluated using a weighted condition indices method on the basis of differential biological significance and the degree of dissemination of each alteration (Costa *et al*; 2012). The changes were consolidated into a single value for a clearer picture of the health status of the bivalve. Results indicated that digestive glands were severely affected than gills. Severe lesions such as tubular atrophy, necrosis, fibroma and parasitosis were typically found in clams from zone1 and 2. Animals from zone3 were the least damaged; however, significant difference was observed in the condition indices of histological lesions in the digestive diverticula of clams collected from 3 different zones ($P < 0.05$). Haemocytic infiltration was repeatedly observed in damaged tissues implying inflammatory response in the inter-tubular tissue of clam from zone 2, preceded by zone 1. The most prevalent parasites found in the gills and digestive diverticula were Nematopsis like protozoan parasites, followed by prokaryotic inclusions, ciliates and trematode sporocysts containing numerous germ-balls and cercariae in different stages of maturity. Alterations in gill epithelia were infrequent in bivalves collected from zone 1, 2 and 3 with the exclusion of parasitosis. Condition indices of gill histopathology were significantly ($P<0.05$) high in zone 2 followed by zone 1 and 3. However, no significant difference was observed between zone 1 and 3.

# Occurrence and effects of isopod *Mothocya renardi* on *Selar crumneopthalmus* (Big Eye Scad)

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Marine capture fishery is highly affected due to the occurrence of diseases and parasites which lead to multiple effects like recruitment pattern of the population of the certain ecologically important fin and shellfishes. The Big eye scad was collected from gillnet catches of Parangipettai coast. In the present study reported the first observation of the isopod parasite *Mothocya renardi* infestation on *Selar crumneopthalmus (Big Eye Scad).* Severe incidence would lead to the extinction of the species in the marine environment, thus it will affect the dependent communities like fishermen in long run.

# Distribution and extracellular enzymes production of cultivable bacteria isolated from pneumatophores of ayiramthengu mangrove ecosystem of Kerala coast

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The present study focuses on the distribution of cultivable heterotrophic bacteria and their extracellular enzyme production. The study was conducted from June to September, 2018 at three different sampling stations of Ayiramthengu mangrove ecosystem. The bacteria were isolated from two distinct regions such as upper and lower of pneumatophore surface from each sampling sites. The different bacterial genera isolated were *Pseudomonas* sp., *Acinetobacter* sp., *Moraxella* sp., *Streptoccoccus* sp., *Deinococcus* sp., *Micrococcus* sp., *Paenibacillus* sp. and *Staphylococcus* sp., of which *Pseudomonas* sp. was the dominant one. The study revealed that highest Total Heterotrophic Bacteria count (THB) was observed on the lower region of pneumatophore at Station 1 ($75 \times 10^4$ cfu/ml). The extracellular enzymes such as amylase, cellulase, lipase and phosphatase were screened with different bacteria. The study showed that phosphatase producing bacteria (78%) was predominant, followed by lipase (75%), cellulase (71%) and amylase (52%). The study indicated the fact that the dynamic characteristics of mangroves provides a nurturing site for diverse bacteria, which were even capable to produce various enzymes.

# Isolation and characterisation of a halophilic archaeon *Halorubrum sodomense* from Manaikkudi saltpans, Tamil Nadu, South India

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Archaea are mostly unexplored and distinct class of microorganism with unique features. They are phylogenetically more similar to eukarya than bacteria. Achaeal membrane lacks peptidoglycan but have different membrane lipid bonding. Archaeal lipids lack the fatty acid found in bacteria and eukaryotes and instead have side chains composed of repeating units of isoprene. They are key players of ocean biogeochemical cycles and potential source of novel natural products including chemicals and biomolecules. Marine solar salterns are centers for the production of common salt from seawater during summer. Archaea are commonly encountered in various extreme environments and saltpans are no exception. The present study attempted isolation characterization of halophilic archaea from a solar saltern situated at Manaikkudi Village in Nagercoil District, Tamil Nadu.

Brine samples were collected from the saltpan in sterile sample bottles and inoculated on to archaeal specific media and incubated. An extremely halophilic, red pigmented archaeon was isolated which was further studied based on morphological, phenotypic and biochemical characteristics as well employing 16S rRNA gene sequence analysis. The isolate was identified as *Halorubrum sodomense*. The genus *Halorubrum* belongs to the family Halobacteriaceae. Members of the genus *Halorubrum* are ubiquitous in hypersaline environments especially in solar salterns. The most members of the family Halobacteriaceae have a high content of bacterioruberin, a 50-carbon open chain carotenoid. Carotenoids are one of the most diverse and broadly distributed classes of pigments in nature with enormous biotechnological applications. *H. sodomense* are strictly aerobic, oxidase and catalase positive. Optimum growth occurs in media containing 25% NaCl. Antibiotic susceptibility of the strain was tested against a panel of antibiotics *viz*., Cholramphenicol, Tetracycline, Amikacin, Erythromycin, Kanamycin, Amoxyclav, Nalidixicacid, Vancomycin, Rifampicin, Carbanicillin, Streptomycin and Penicillin. It was found that the strain was resistant to all the tested antibiotics except Rifampicin. This is the first report on isolation and identification of *Halorubrum sodomense* from India, which could be a potential source of bacterioruberin carotenoid as well as a source of halotolerant genes.

# Ultrastructural study of terminal ampoule of the green tiger prawn *Penaeus semisulcatus* de Haan

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Present study was concentrated on the ultrastructural details of terminal ampoule of male shrimp *Penaeus semisulcatus* de Haan to know the view of spermatophore containing with sperm mass. For the present study, the technique recommended by Felgenhauer (1987) for preparing crustacean tissues for scanning electron microscopic studies was used. The tissues of terminal ampoule and vas deferens of male were prefixed in buffered glutaraldehyde, dehydrated in an ethanol series (35% to 100%) critically point dried on CO2 and sputter-coated with gold palladium, mounted and observed. The transverse section of the terminal ampoule has been studied in detail by Scanning Electron Microscopy. It showed that the terminal ampoule is formed of three Chambers (1, II, III) and five spermatophoric layers. The sperm mass is accumulated in chambers I and II. chamber I contains sperm mass which is surrounded with PSL on which the adhesive layer is deposited. With the continuing invagination of primary spermatophore layer, chamber II is found with full of sperm mass. The spermatophore layer III is deposited on the SSL and is made up of glutinous material. Chamber III is an empty concave pouch without sperm mass, but surrounded by thick plate-like spermatophore layer IV. Chamber IV is located. in the distal region of the terminal ampullae. This chamber contains the wing portion of the spermatophore and is made of spermatophore layer V which is reticulate or corky in appearance. The respective accessary layer I or II located on the chambers I and II are known to function as a supportive sheath for the sperm mass and the spermatophore layers I and II. The function of the dorsal plate made of spermatophore layer IV is to attach the spermatophore onto the thelycum, while the anterior portion of the spermatophore is anchored by the wing or the spermatophore layer V.

# Infestation of gill copepod, *Lernanthropsis mugilii* and its effect on grey mullet, *Mugil cephalus*

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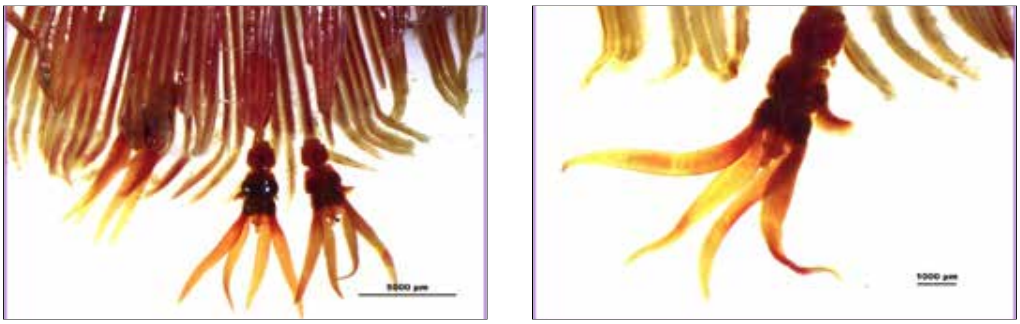
Grey mullet, *Mugil cephalus* (Linnaeus, 1758) is one of the most promising economically important brackishwater candidate species. *M. cephalus* (n=45) of was maintained in a 100 MT capacity outdoor flow-through tank system with 30% water exchange at Muttukadu Experimental Station (MES) of ICAR-Central Institute of Brackishwater Aquaculture (ICAR-CIBA). The average weight and length of the fish were 748.10±25.13 g and 455.75±13.41 mm, respectively. The fishes were fed with Mullet Brood[plus], (a brood stock feed for grey mullet, pellet size-6 mm; crude protein-38%; crude lipid-10%) at 3.5% of body weight twice daily. Mass mortality (40%) was observed over a period of one week with clinical signs such as dullness, depression, inappetence, erratic swimming, gasping for air, lethargy, loss of equilibrium and anaemia. Fishes were examined for the presence of parasitic infestations. Post-mortem examination revealed that there were cutaneous haemorrhages, anaemic and blanched abdominal viscera. One species of copepod belonging to the *Lernanthropsis mugilii* (Shishido, 1898) was found parasitic on the gill filaments as shown in Figure 1. The prevalence of *L. mugilii* was 100% with the parasitic intensity of 24.5±2.9 per fish. The parasitic male and female sex ratio was 1:2.96. Mature adult female parasites were identified based on oblong cephalothorax and egg-strings. Mature adult male and female were measuring about 6.48±2.93 and 12.40±11.91 mm in length respectively. The infected gill was pale with excessive mucus production. Blood parameters showed severe anaemia as shown in Table 1. Heart blood swab bacterial isolation did not reveal any pathogenic bacterial infection. Histopathological investigation showed that there was erosion, haemorrhages, hyperplasia, fusion and necrosis of gill filaments with nodule formation and chronic inflammation. Chronic inflammation and amyloid degeneration in kidneys, chronic inflammation in the liver and immature ovary were also observed microscopically. From this study, it was concluded that the mass mortality in grey mullet could be due to *L. mugilii* (Shishido, 1898) infestation associated anaemic anoxia.



*Lernanthropsis mugilii* (Shishido, 1898) was found parasitic on the gill filaments of *Mugil cephalus* (Linnaeus, 1758).

Haematology of grey mullet, *Mugil cephalus* infested with *Lernanthropsis mugilii* (Mean±SE).

| Parameters | Control without parasite | Infested with parasite |
|---|---|---|
| RBC (x10$^{6}$ mm$^{3}$)** | 9.27±0.07$^{a}$ | 2.20±0.23$^{b}$ |
| WBC (x10$^{3}$ mm$^{3}$)** | 156.33±0.58$^{a}$ | 87.92±2.32$^{b}$ |
| Haemoglobin (g/dL)** | 5.33±0.44$^{a}$ | 2.33±0.44$^{b}$ |
| PCV (%)** | 18.07±0.81$^{a}$ | 7.47±0.72$^{b}$ |
| MCV (fl) | 19.51±1.02 | 35.12±6.61 |
| MCH (pg)* | 5.75±0.46$^{a}$ | 10.53±1.60$^{b}$ |
| MCHC (g/dL) | 29.78±3.52 | 32.99±8.99 |
| Elongate thrombocyte (%)** | 25.67±1.45$^{a}$ | 14.33±1.20$^{b}$ |
| Oval thrombocyte (%) | 7.33±0.88 | 5.00±0.58 |
| Total thrombocyte (%)** | 33.00±1.53$^{a}$ | 19.33±1.20$^{b}$ |
| Large lymphocyte (%)* | 11.00±1.53$^{a}$ | 17.00±1.16$^{b}$ |
| Small lymphocyte (%)* | 22.67±2.03$^{a}$ | 30.67±1.20$^{b}$ |
| Total lymphocyte (%)** | 33.67±0.88$^{a}$ | 47.67±1.45$^{b}$ |
| Juvenile neutrophil (%) | 3.67±0.67 | 5.33±0.33 |
| Mature neutrophil (%) | 5.33±0.88 | 4.33±0.67 |
| Total neutrophil (%) | 9.00±1.53 | 9.67±0.33 |
| Myelocyte (%) | 14.00±0.58 | 10.67±1.20 |
| Monocyte (%) | 10.33±1.20 | 12.67±1.76 |

**P<0.01, *P<0.05.

$^{a,\,b}$–Values bearing different superscripts in a row differ significantly

# Ecotype-modulation of serum biochemical attributes in *Lutjanus argentimaculatus* (Forsskal, 1775)

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Environment plays an important role in designing husbandry practices in fish culture like health management, especially when the fish is under captivity. However, the profound influence of environment in modulating health of the fish is under-studied for most of the commercially important fish species limiting the application of different health indices directly for monitoring fish health. The great plea in seafood industry coupled with high market value of *Lutjanus argentimaculatus* (Forsskal, 1775) makes it as one of the most important candidate species for aquaculture worldwide. Considering the influence of ecosystem in energy metabolism and serum biochemical indicators of fish, the present study was aimed to study the influence of ecotype on 9 relevant serum biochemical attributes (glucose, protein, albumin, globulin, albumin/globulin ratio, cholesterol, triglycerides, serum glutamate oxaloacetate transaminase, SGOT and serum glutamate pyruvate transaminase, SGPT) of this supreme aquaculture candidate. For this, a total of 24 wild fish (14 males and 10 females) with an average length of 22.48 ± 4.2 cm and average weight of 235.66 ± 87.2 g were collected from 4 random sites along Kerala west coast during March-May, 2018. Simultaneously, fish (n=24) including 9 males and 15 females) with an average length of 26.8 ± 1.56 cm and average weight of 316 ± 85.1 g maintained in 3 brackish water cages were also collected. The mentioned 9 serum biochemical parameters were evaluated individually for each collected sample and species specific reference intervals for these biochemical attributes were calculated. Afterwards, comparison between different parameters with respect to ecotype were carried out using, independent sample t-test and the results have shown that ecotype had a significant role on modulating serum biochemistry, except on serum glucose and SGOT levels; suggesting the prime importance of estimating ecotype specific reference intervals for interpreting fish health. When the data on serum biochemical attributes, for which ecotype was found to have influence were subjected to principal component analysis (PCA), it was found that 2 principal components were sufficient to explain most of variation (91.7%) in the data set. Thus, the first two principal components were extracted for interpretation which indicated that there was a distinct difference between the serum biochemical parameters of fish taken from 2 ecotypes as all data points in both ecotypes maintained a non-overlapping distinct groups that were graphically separated along the projected plane, with fish from same ecotype lied close together. Interestingly, intra-ecotype variation for these 7 serum attributes were substantially less indicating the regularity of these parameters within a specific habitat and all these 7 biochemical parameters were observed to be higher in cage cultured fish compared to their marine wild counter parts. In sum, the results suggested that interpretations on serum biochemistry of the fish species have to be done based on the values of similar ecotypes for strategizing effective health management under captivity. Further, the data on serum biochemical attributes, for which habitat was found to have influence were analyzed to establish the ecotype specific reference intervals for *L. argentimaculatus*. In conclusion, the results of the present study provide thought-provoking insights on serum biochemistry of *L. argentimaculatus* and ecotype based modulation of these parameters.

# Morphological and molecular characterization of two new species of *Ceratomyxa* (myxosporea: ceratomyxidae) from marine ornamental fishes off Vizhinjam coast, Kerala

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Myxosporeans are a group of spore forming metazoan parasites infecting predominantly fishes and sometimes amphibians and reptiles. They have a complex life-cycle which involves annelidan worms and fishes, with each host producing different types of spores. Myxosporeans have a wide range of distribution and more than 2400 species under 62 genera have been reported so far. *Ceratomyxa* The´lohan, 1892 is one of the largest genera under myxosporea usually infecting the gall-bladder, while some species were also observed infecting the urinary bladder.

Two novel species of *Ceratomyxa* are described from the gall bladder of the marine ornamental fishes, *Acanthurus xanthopterus* and *Acanthurus nigrofuscus* collected from Vizhinjam, along the south west coast of India. Prevalence of infection in *A. xanthopterus* and *A. nigrofuscus* is 85% and 100% respectively. Species delineation is based on a combination of spore morphology, morphometrics, host, organ of infection, geographic location, and molecular and phylogenetic analyses. Mature spores recovered from the gallbladder of *A. xanthopterus* were slightly crescentic in shape with rounded ends, convex anterior margin and slightly concave posterior margin. Spore valves equal in length, joined by a straight suture line. Spores (n=30) measured 5.17 ± 0.64 μm in length and 14.25 ± 1.5 μm in width. Polar capsules equal, spherical in shape and measured 2.0 ± 0.16 μm long and 1.94 ± 0.16 μm wide situated near the sutural line at the anterior pole of the spore. Polar filament with 4 coils, measured 21.17 ± 0.64 μm in length. Posterior angle measured 169.14 ± 4.85$^{0}$. Early sporogonic stage spherical to irregular in shape. Monosporic, disporic and multisporic plasmodial stages were present, spherical to irregular in shape with filopodia over their body. Abnormal spores with three polar capsules were also observed. Comparison of the present myxosporean with related species of *Ceratomyxa* revealed marked morphological and morphometric differences. Partial SSU rDNA sequence obtained from the present isolate was 1431 bp long. In BLASTN analysis, the sequence showed highest identity (92.26%) with *C. diplodae* isolated from *Dicentrarchus labrax*. The present species shows least genetic diversity to *C. puntazzi* (8.8).Other compared sequences along with *C. diplodae* and *C. puntazzi,* showed still lower molecular identities and higher divergence values, suggesting that the present species is molecularly distinct.

Mature spores recovered from *A. nigrofuscus* were slightly crescentic in shape with rounded ends and measured 5.11 ± 0.59 μm in length and 18.47 ± 2.02 μm in width. Spore valves equal, with irregular sutural line. Two equal, spherical polar capsules situated near the sutural line at the anterior pole of the spore, measured 2.23 ± 0.32 μm long and 2.11 ± 0.27 μm wide. Polar filament with 3 or 4 coils and measured 21.85 ± 0.41 μm in length. Posterior angle measured 168.56 ± 9.3$^{o}$. Spherical to irregular shaped early sporogonic stages with one, two or more filopodia observed. Abnormal spores with three polar capsules were also observed. Comparison of the present myxosporean with related species of *Ceratomyxa* revealed significant morphological and morphometric differences. Partial SSU rDNA sequence obtained from present isolate was 1418 bp long. In BLASTN analysis, the sequence shows highest identity (90.43%) with *C. puntazzi* isolated from *Sparus aurata*. The present species showed least genetic diversity (7.9) with *Ceratomyxa sp.* 1 LFR 2017. Other compared sequences showed still lower molecular identities and higher divergence values, suggesting that the present species is molecular uniqueness.

In phylogenetic analysis, both the species clustered with the *Ceratomyxa* clade. Considering the morphologic, morphometric, molecular and phylogenetic differences with the previously described species of *Ceratomyxa*, the above described two species are treated as new and named *Ceatomyxa xanthopteri* and *Ceratomyxa nigrofuscuae*.

Theme-5 Marine biotechnology and bio-marine products
(disease detection, surveillance and control)

# *Neoechinorhynchus cephali* n. sp. (acanthocephala: neoechinorhynchidae) from the flathead grey mullet *Mugil cephalus* (Linnaeus, 1758) from the south-west coast of India

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Acanthocephalans are spiny-headed worms inhabiting the intestines of vertebrates. The present study attempts to describe and identify an acanthocephalan recovered from *Mugil cephalus* (Linnaeus, 1758) using morphology, morphometry, scanning electron microscopy and molecular and phylogenetic analysis.

The parasites were recovered from the fore- and mid-gut regions of *M. cephalus.* The presoma of the parasites was embedded within the intestinal wall while the metasoma was lying free in intestinal lumen. The parasites exhibited a prevalence of 14.28 % and intensity of 25 parasites/host. Morphologically, the parasites appeared small, cylindrical, slightly curved and creamy white in color. Males are smaller than females, measured 3.22-8.50 (5.65 ± 1.91) x 0.411-0.978 (0.664 ± 0.186) mm while female specimens measured 6.63-11.79 (8.87 ± 1.76) x 0.57-1.27 (0.88 ± 0.22) mm in size. Proboscis short, globular and were armed with 3 spiral rows of 6 hooks each. An apical organ was present in the proboscis with two oval shaped nuclei at the middle region. Anterior hooks appeared larger and stouter than the rest and the hook size decreased progressively towards the posterior. Body wall characterized by the presences of 5 nuclei on dorsal side and 2 on ventral side along with lacunar canals connected by circular anastomoses. Proboscis receptacle sub-cylindrical in nature, a para-receptacle and ampulla were also visible on one side of receptacle along with a roughly triangular ganglion at its base. Lemnisci filiform, sub-equal with one to two giant nuclei each. Testes are contiguous, post-equatorial and densely packed with nuclei followed by a syncytical cement gland having four giant nuclei. Males with everted copulatory bursa manifested numerous round, sensory cells. Eggs elliptical in shape with concentric shells, polar prolongation of fertilization membrane absent, eggs measured 15.17 – 20.95 (17.64 ± 2.98) x 3.88 – 4.89 (4.47 ± 0.52) μm in size. Morphological features indicate that the present acanthocephalan belongs to the genus *Neoechinorhynchus,* (Neoechinorhynchidae) Hamann, 1892.

Ultra-structural studies were carried out using a Tescan VEGA3 scanning electron microscope. In SEM studies proboscis hooks appeared robust, slightly curved and tapering with a pointed tip while the hook surface appeared rough with longitudinal striations.

Molecular and phylogenetic analysis based on ITS1-5.8s-ITS2 region of the ribosomal DNA consistently revealed a strongly supported, distinct clade for *Neoechinorhynchus*. The present species appeared as a separate sister clade within the *Neoechinorhynchus* cluster in both maximum livelihood and neighbour joining trees. Based on the morphology, morphometry, and molecular and phylogenetic analysis coupled with host and geographic location, the present species infecting *M. cephalus* is distinct from all previously described species of *Neoechinorhynchus* and hence considered novel and the name *Neoechinorhynchus cephali* n. sp. is proposed.

# Monogenean infestation in selected wild and cultured carangid fishes from Vizhinjam, Thiruvananthapuram

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Carangid fishes (Teleostei: Carangidae) are commercially important food fishes and have great aquaculture potential. Monogeneans are common ectoparasites which can flare up in a short time and these are reported to cause serious loss in fish culture. This study was conducted to determine the prevalence, mean intensity and relative abundance of monogeneans on body surface and gill filaments of selected wild and cultured carangid fishes.

Nine species of carangids (*Alepes djedaba*, *Atule mate*, *Carangoides malabaricus*, *Caranx heberi*, *Caranx melampygus, Caranx sexfasciatus*, *Decapterus macrosoma, Decapterus russelli* and *Trachinotus mookalee*) were surveyed between April 2018 and May 2019. A total of 144 fishes were examined for monogenean parasites. The monogenean parasites were removed from the body surface and gill filaments and counted using a stereozoom microscope. For the morphological study, the extracted monogeneans were mounted on a slide by using drop of ammonium picrate-glycerine (APG) and then were observed under the compound research microscope. The monogenean parasites were identified based on the characteristics of the morphology and morphometrics of the parasite, which did not differ significantly from the previous descriptions of the same species reported from other geographic locations.

Five monogenean (*Heteromicrocotyloides sp., Heterobothrium sp., Neobenedenia girellae, Protomicrocotyle sp.* and *Pseudaxine sp.*) species from 4 families were recorded. Four species were found on gill filaments and one on the body surface. The maximum prevalence was recorded in cultured *Trachinotus mookalee* (100%) and the minimum was in *Decapterus russelli* (8.33%). The intensity of infection ranged from 1 to 26.3 and the relative density (abundance) ranged from 0.08 to 26.3. The monogenean parasites were carefully recorded and the data obtained was tabulated and summarized. Estimating the actual harm to fish caused by the presence of parasites is not easy even in cultured fish, unless the infestation is severe; hence it is almost impossible in wild fish populations. Furthermore, it should be emphasized that the presence of a parasite does not necessarily imply manifestation of a disease. In aquaculture, some parasites like monogeneans are able to reproduce rapidly and heavily infect a large proportion of fish which may lead to diseases with significant economic consequences.

# Monogenean parasite, Benedenia sp. infestation in Indian pompano, *Trachinotus mookalee* (Cuvier, 1832) and its control measures

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Parasitic infection in Indian pompano, *Trachinotus mookalee* and its control measures in captive conditions were studied. The hatchery produced Indian pompano seeds were stocked in five 6 m diameter cage installed in Bay of Bengal off Visakhapatnam. The fishes were fed on artificial pellet containing 40% protein and 10% lipid. After a culture period of 5 months, the fishes showed lethargy and sluggishness during the feeding activity in the cages. Even few fishes were found to be dead and floating on the surface. The moribund as well as live fishes were collected from each cages and examined for any parasitic infection following standard protocol. The monogenean parasite of the genus *Benedenia* was identified from the moribund as well as infected cultured fishes. Thirty fishes from each cage were taken out live and treated in fresh water to collect the parasite to estimate the mean intensity as well as prevalence of the parasite. The mean intensity of *Benedenia* sp. in cultured fishes was found to be 89.98 ± 12.59 and the prevalence was found to be 100%. Infected cultured fish cages were randomly assigned to four treatment groups (Group A, B, C and D) and one control group (E). Group A fishes were given dip treatment in freshwater for 10-15 min and the fishes were shifted in another cage after the freshwater treatment, whereas group B, C, and D were fed with feed containing Praziquantel @ 2.4, 3.6 and 4.8 g/kg of feed twice daily at the @ 2% body weight per day for 10 days. The parasites were not found immediately in freshwater treated group A; however after one week of treatment, parasites have been observed in freshwater treated fishes. The fishes fed with medium and higher doses (group C and D) of the Praziquantel were free of the infestation and no re-infestation was seen in them even after two months. The group which were fed on lower dose (group B) were infected with parasite even after 10 days of feeding; however the intensity was significantly ($p< 0.05$) low compare to the control group (E). This is the first study to confirm *Benedenia sp.* infestation in Indian pompano; and, that Praziquantel (3.6 g/kg feed) is able to control the infestation effectively. This study will help in developing the health management protocol during the culture of Indian pompano in cages.

# Visualizing the scientific panorama of Coral black band disease research: A Bibliometric analysis

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Coral reefs are facing serious decline and disease has been a major contributor. Black band disease (BBD) has been bestowed with a foremost position in the top five topics addressed in the coral disease research literature underpinning its paramount role in the field of coral disease. Being the first ever disease reported in corals, this relevant disease has wide global distribution in Caribbean basin, the Indo-Pacific including the Red Sea and in Great Barrier reef (GBR). Lack of previous evidence on global bibliometric analysis forms the background of this study that aims to assess the research activities and trends on BBD using the open-source Bibliometrix R-package. Bibliometrics is functionally different from the traditional review of literature as this focus more on the statistical related data on literature rather than a conventional descriptive history of the related research topic or field. The current study aims to decipher the statistics of research progression, characterise the knowledge domain, scientific productivity, examining the research front and the nature of the collaborations thereby comprehending the global black band disease research.

Data related to BBD from scientific publications indexed at Elsevier's SCOPUS Collection and Clarivate Analytics Web of Science were collected. The data was analysed using bioblioshiny package of statistical software R 3.5.2 which provides results as charts, bargraphs, vector maps and networks. Assessment of author productivity summarizes that majority of the scientific literature emanated from smaller group of researchers with 70% of authors contributing only single articles. The study shows that the prominent collaboration in global BBD research is a trio between the USA, UK and Australia which is highly remarkable. Our findings suggest there is lack of research contribution by most commonwealth countries. This indicates that the BBD research requires more focus and fostering in many of the developing countries and this needs further active research collaborations with the developing countries. Thematic map reveals BBD research revolves around the basic themes like "disease prevalence" but currently interest has been shifted towards specialized theme like "microbial community". Analysis of BBD publications indicate that treatment methods, resistance and coral immunity against BBD were some of the under looked areas in the research. The bibliometric report can act as a reference for coral scientists and policy makers to tackle Black band disease.

# Morphological divergence in Indian oil sardine, *Sardinella longiceps*: can it be correlated with habitat variability?

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Morphological divergence has been implicated in Indian oil sardine collected from different geographic locations and seasons. Three variants mainly slender, stout and Oman have been delineated based on morphometric comparisons using principal component analysis. In the present investigation, we tried to correlate sardine morphological variability with the physico-chemical parameters of the habitat (average sea surface temperature, chlorophyll a and dissolved $O_2$ values) in which each of the sardine variants are predominantly found.

Oman sardine found in Oman waters has comparatively more body depth, weight and condition factor. Chlorophyll-a concentration which is an indirect measure of productivity is highest in the Northern Arabian Sea (4-10 mg/m$^3$) which encompasses Oman waters which may be the reason for the comparatively higher condition index of Oman sardines. In addition, Northern Arabian Sea is comparatively cooler than South East Arabian sea and Bay of Bengal (highest temperature (24-27ºc) during the North East monsoon season (October-March) and lowest temperature (20-22ºc) during the Southwest monsoon season (June–September)) which also results in lower metabolic rate, increase in available oxygen and increase in average size. On the contrary, temperature, chlorophyll-a and oxygen content in south eastern Arabian sea exhibits wide fluctuations over the year ( Chlorophyll-a peaks during July and August (5-10 mg/m$^3$) and recedes by October (1-2 mg/m$^3$)) with average values of chlorophyll-a and oxygen lesser than Northern Arabian sea while temperature is higher. These factors influence the average body size of sardines caught from this region as low productivity and higher metabolic rate and lower levels of oxygen constrain the body size of fishes. Chlorophyll-a content of south west Bay of Bengal is low on an average throughout the year and the slender sardines might be the adults of larvae that spawned during low oceanic productivity.

Fishing pressure of respective regions also will be a driver of size variations as Oman waters exhibit the lowest fishing pressure in terms of number of fleets and days of fishing. These patterns of size variations should be investigated in other pelagic and demersal fishes from all these regions so that valid conclusions could be made. Climate change may exacerbate size variations as warmer waters will contain lesser oxygen and consequent reductions in body size.

# High throughput sulphur oxidizing microbial screening assay targeting environmental microbiology applications

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Biological oxidation of sulfur is a vital metabolic process in natural environment, accomplished through a group of microbes known as sulfur oxidizing bacteria (SOB). Accumulations of reduced sulphur are highly detrimental in the environment because of acute neurotoxicity towards human and animals, undesirable odour and corrosive nature to metallic infrastructures; which can be minimized by the use of potential SOB. Further, SOB have wide technological applications in the mitigation of sulphur deficiency in soils, waste water treatment plants and desulfurization of biogas *etc*. This, recently growing interest in the application of SOBs, have led to increasing search of potential SOBs from various ecological niche. Screening approaches for SOB stems on the analytical techniques for the quantification of sulphates including gravimetric, volumetric, spectrophotometric, ionic chromatography and capillary electrophoresis methods. Even though each of these techniques have their own merits, spectrophotometric technique based on the precipitation of sulphates with barium chloride solution is considered to be the most reliable and cheap method. However, for screening a large numbers of strains to identify potential SOBs, a cost effective and reliable high throughput method is necessary. Our intension was to extrapolate the standard turbidometric assay into a microtitre plate based platform with the objective of achieving a fast and simple method for the simultaneous monitoring of many SOB cultures. Further, the assay was optimized to cover a higher sulphate concentration which is initially present in SOB media; in which the results of the ordinary (macro-volume) turbidimetric assay was not reliable. Initially assay was conducted in varied concentration of different reagents to find out the minimal optimum concentration of all the reagents to get the maximum $R^2$ value within the recommended range of the ordinary (macro-volume) turbidimetric assay (1-40 mg/L) using sodium sulphate as standard. The final optimized assay having the minimal reagents was having $R^2$ value of 0.9925 within the recommended range. Subsequently, the optimized assay was conducted in higher sodium sulphate concentrations to check whether it can be applied for the microbiological screening purposes which require reliable readings within the range of 0-1500 mg/L (Media contains 1000-1500 mg/L thiosulphate). It was found that the optimized assay was linear over this sulphate concentration and linearity was expressed through the regression equation $y = 1.2426x + 0.0115$ with regression coefficient of 0.9976. When the calibration curve was established using the ordinary turbidimetric assay with the simultaneous screening of solutions containing varied sodium sulphate concentrations ranging from 0-1500 mg/L, the regression coefficient of the linearity was only 0.8721, indicating the superiority and applicability of the optimized assay for microbiological applications. Further, selectivity coefficient of the optimized assay for sulphate over thiosulphate (present in the media) was calculated as 0.003 ± 0.005 indicating that the method has very high selectivity for sulphate within the 0-1500 mg/L concentration. There was a close the agreement between 12 individual analyses over the analyzed range with an average 3.55% repeatability tolerance, indicating high precision of the assay. Limit of detection (LOD) and limit of quantification (LOQ) for the optimized assay was calculated as 0.003 mg/ml and 0.009 mg/ml of sulphate concentration. The sensitivity above the LOD was 1.30 ± 0.224. The method was found to be very robust in varied pH from 4-9. Accuracy of the optimized assay in 1: 4 diluted heterotrophic and 1: 32 diluted autotrophic SOB media was then calculated as 104.06 ± 7.21 and 102.01 ± 5.23 recovery % respectively indicating high accuracy. In short, optimization and validation of a microtitre plate based sulphur oxidizing microbial screening assay was done through the present study targeting its final *in-house* applications for a large number of environmental isolates.

# Fish meal replacement with marine microalgae, *Coelastrella vacuolata* meal in the diet of percula clown fish, Amphiprion percula

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Marine microalgae. *Coelastrella vacuolata* is a genus of green algae in the family Scenedesmaceae. Culture and harvest of this alga is comparatively easy as this alga tends to settle at the bottom of the tank once it reached the lag phase. Size of this algal cell is 7 to 11 μm. This algae is rich in keto-carotenoids with a considerable proportion of astaxanthin and canthaxanthin. Total protein content of *Coelastrella vacuolata* meal is comparatively lower than fishmeal and also contain meager amount of lipid content.

A 30 days experiment was conducted to evaluate the effect of *Coelastrella vacuolata* meal in the diet of fries of *Amphiprion percula* in place of fishmeal as an alternate ingredient on growth, feed utilization and skin colour intensity. The juveniles of percula clown fish, *Amphiprion percula* with the average weight of 104±4 mg were selected and randomly stocked in five treatments each with triplicates. There were five experimental diets with 40% crude protein and 8% crude lipid were prepared with the inclusion of graded level (0, 5, 10, 15 and 20%) of *Coelastrella vacuolata* meal (CM) and fed to five different treatments namely 0CM, 5CM, 10CM, 15CM and 20CM respectively. The experimental fishes from each treatment were fed to apparent satiation twice daily (10:00 and 16:00hrs) during the period of feeding trial. Round the clock aeration was provided throughout the experimental period. At the end of experiment, the fishes were sampled for the estimation of growth parameters.

The result indicates that there was no significant difference ($P > 0.05$) in the growth data among the different treatments. Higher length gain percentage of 53.19% was noticed in 10CM group. Higher weight gain percentage of 254.74% was witnessed in 0CM group followed by 10CM group. Better specific growth rate was observed in 0CM group followed by 10CM group. The average daily growth (ADG) was in the range of 7.95-8.58 mg and the maximum ADG was recorded in 0CM diet fed groups. Feed utilization parameters, feed conversion ratio (FCR) and feed efficiency ratio (FER) showed significant difference ($P < 0.05$) among the treatment groups. Better FCR of 1:2 was noticed in 0CM group and least FCR of 1:2.16 was recorded in 15CM group. The FER also showed similar trend as the trend witnessed for FCR. This indicated that *Coelastrella vacuolata* meal can be utilized as a feed ingredient in the diet of *Amphiprion percula*.

# Quantitative expression of Hsp70 gene in brown mussel *Perna indica*

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The brown mussel, *Perna indica (Kuriakose and Nair, 1976)* is an important marine intertidal bivalve mollusc species native to India. It has restricted distribution along the southern Indian peninsula prominently from Kollam (Kerala) through Kanyakumari to Thiruchendur (TamilNadu). It is commercially valuable due to dietary and medicinal properties and the sensitivity to stress make it an ideal candidate to study the impact of pollution. Stress is a condition that disturbs the homeostasis of an organism. Intrinsic or extrinsic factors can act as stressors which induce variations in their normal cellular responses mediated by different genes like heat shock protein genes (*Hsp70*), metallothioneins, antioxidant enzymes, etc. The survival of the organism depends on the success of these cell responses. Here, we display a tissue level expression profiling of *HSP70* gene in the Indian brown mussel, *P. indica* using quantitative PCR (qPCR). Different tissue types were showing different levels of the gene expression under normal temperature conditions. The expression level found to be more in the gills followed by the adductor and mantle tissues. As the mussel is exposed to varying abiotic stress factors like temperature and oxygen on a regular basis owing to the harsh and challenging environment, the stress management genes like *Hsp70* are constitutively expressed. The results obtained in this pilot study using Real Time PCR/qPCR indicate the constitutive expression of *Hsp70* in different tissues with highest peak in the exposed tissue-gills. The real time results are also in agreement with previous reports with semi quantitative methods and this is the first quantitative study of *HSP70* gene expression in *P. indica*. Further studies with challenge trials are underway which will bring lights on the induced expression of these genes on exposure different challenges.

# Morphological and molecular descriptions of a new species of *Myxobolus* (Myxosporea: Myxobolidae) from mullets in Cochin backwaters, Kerala

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Myxosporeans are exclusively microscopic metazoan parasites of lower vertebrates. Coelozoic myxosporeans inhabit the lumen of hollow organs such as the urinary tract and gall bladder and, are usually specific to these sites. While, histozoic forms appear as small cysts, up to one or more millimetres in size, on different organs. Myxosporidians have a complicated life cycle, involving a fish as definite host and an annelid or bryozoan as intermediate host. Spores that develop in both hosts have different morphologies but possess key features demonstrated by all myxozoans. These developmental stages and spores were designated as myxosporeans and actinosporeans in their respective fish and worm hosts. The genus *Myxobolus*, Bütschli, 1882 comprise of more than 900 species and is the most speciose within the phylum Myxozoa. The mullets (Mugilidae), are found worldwide in coastal temperate and tropical waters, including estuaries and lagoons, and serve as an important food source.

A novel sp. of *Myxobolus* infecting mullets from Cochin backwaters is described. *Liza macrolepis*, coming under the family Mugilidae collected from three different sites in Cochin backwaters, along the southwest coast of India revealed *Myxobolus* infections in their gill filaments. Mature spores were ovoid in valvular view, biconvex in sutural view and measured 6.55 ± 0.32 × 5.39 ± 0.26 μm in size. Polar capsules were pyriform, equal in size and measured 3.17 ± 0.29 × 1.94 ± 0.26 μm in size. Polar filaments form 5 coils and are arranged obliquely to the polar capsule axis, and measured 29.61 ± 4.75 μm in length when extruded. Shell valves smooth. Binucleate sporoplasm with two rudimentary nuclei and a vacuole. The elongated pseudocysts are milky white with smooth outline, and measured 1374.54-2187.12 (1782.9 ± 358.9) μm x 70.63-125.41 (108.27 ± 24.07) μm in size, attached to the gill filaments. A comparison of the present *Myxobolus* with related forms revealed significant morphological & morphometric differences. Results of the principal component analysis indicated that the three isolates of the parasites from different locations in Cochin backwaters were similar. In BLASTN analysis, the sequence of the present myxosporean showed highest identity (84.88%) with *M. episquamalis* isolated from *Mugil cephalus* in Korea and least identity (80.27%) with *Myxobolus sp.* 1 PBS-2015 isolated from *Distichodus nefasch* in Kenya. Molecular identity between the three isolates of the present parasite from various locations was 100% indicating their conspecificity. Other compared sequences along with *M. episquamalis* and *Myxobolus* sp. showed still lower molecular identities and higher divergence values, suggesting that the present species is molecularly distinct.

In phylogenetic analysis, isolates of the present parasite clustered within the *Myxobolus* clade and occupied a separate position with high (100%) boot strap value. Considering the morphological, morphometric, molecular and phylogenetic differences with the previously described species of *Myxobolus* the above myxosporean is treated as new and named *Myxobolus cochinensis* n. sp.

# A shot gun sequencing approach for quantitative analysis of heavy metal resistome and resistant microbial diversity of Mangalavanam mangrove

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Mangroves are a tropical ecosystem in the flood plains of tides and located in the transition zone between land and sea. This is a valuable haven for diverse organisms (including aquatic animals, birds, reptiles, mammals and microorganisms) and is one of the most productive ecosystems in the world (Sheaves, 2005). A total of 1, 81,000 km$^2$, i.e. about one fourth of the world's coastal area worldwide is covered by mangrove forest. According to the forest survey of India study in 1999, out of 4, 87,100 ha of mangrove wetland in India, nearly 56.7% (2,75,800 ha) is present along the east coast. The west coast covers around 23.50% (1, 14, 700 ha) and the remaining 19.8 % (96, 600 ha) is found in the Andaman and Nicobar islands. Managalavanam mangroves located at 90°59' N latitude and 76°16' E longitude, situated at the centre of Cochin (Kochi) city, India, acclaimed as the commercial capital of Kerala, and Gateway of South, is part of a continuous chain of lagoons or backwaters along the Arabian Sea coastal region. The rapid urbanization of this area has resulted in a steady reduction of water levels due to considerable construction and escalation in chemical discharges into the marine environment from factories over the past decade.

Mangrove micro organisms' specifically bacterial communities act as a sink for carbon, processing most of the energy and nutrients in the tropical aquatic systems. They play significant roles as mineralizers of organic detritus and recyclers of essential nutrients. Bacteria in tropical aquatic sediments are ultimately controlled by inputs of dissolved and particulate detritus, natural mortality and recycling. The ecological disturbance to this sensitive ecosystem is proceeding at an alarming rate; hence restoration of the natural geochemical profile and microbial consortia in the sediments is necessary to replenish damaged ecosystems in the tropics. In estuarine pollution, heavy metals are of particular concern due to their environmental and ecological impacts. There is, at present, a growing concern about the inflow of heavy metals to the marine environment and the subsequent effects these metals might have on marine biota (Chen *et al*., 2006; Tranchina *et al*., 2008). Microorganisms have developed metal-resistance mechanisms in order to survive in contaminated environments (Bruins *et al*., 2000). There is an extensive body of literature on anthropogenic intervention and accumulation of heavy metals in the Vembanad-Kol wetland (Haldar *et al*., 2019; Shyleshchandran *et al*., 2018). Concentration of zinc was reported to be to higher compared to other heavy metals, i.e., Cu>Cd>Pb>Hg (Shyleshchandran *et al*., 2018). The fate of the pollutants depends mainly on various factors like oxic/anoxic environment, organic matter, sulfide chemistry, presence of iron species, and other physical parameters. Co-precipitation of iron hydroxide along with scavenging of other metals could be the principal mechanism behind the accumulation of Cadmium, Copper, Lead and Zinc in the estuarine sediments (Singh *et al*., 1984). The estuarine processes are complex on account of their dynamic nature and hence, their transformations often remain obscure. Turbulent mixing of fresh water and seawater can generate rapid changes in Eh, pH, salinity and trace element concentrations (Feely *et al*., 1981).

In this context, the present study was undertaken to investigate the abundance of metal-resistance genes in Mangalavanam mangrove samples and the resistant community composition of the impacted ecosystem. Whole genome shotgun sequencing was performed to assess the taxonomic composition and gene distribution in the ecosystem. To the knowledge of the authors, this is the first metagenomic investigation of the taxonomy and abundance of metal-resistance genes in Mangalavanam mangrove samples. The data generated in the study was compared to datasets of similar impacted ecosystems, with respect to microbial taxonomy and functional responses encoded by heavy metal resistance genes.

# Effect of thermal stress on growth, survival and feed utilization in Snubnose pompano, *Trachinotus blochii* (Lacepede, 1801)

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An experiment was conducted to determine the effect of thermal stress on growth, feed utilization and haematological responses of snubnose pompano, *Trachinotus blochii*. The experiment was conducted for a period of 6 weeks on 15 numbers of rectangular FRP tanks (60 × 100 × 50 cm, 300 L capacity) covered with HDPE nets to avoid leaping of fishes. Fishes with the average weight of 4.11± 0.1 g were randomly stocked in five treatments each with triplicates with varying level of elevated temperatures (29, 30, 31, 32 and 33$^{O}$CW). Each level of temperature is treated as separate treatment 29C, 30C, 31C, 32C and 33C. Temperature in each treatment was maintained by one or two number of 500 W AquaZonic digital thermostat. All the fishes in the experiments were fed with slow sinking crumble feed (1.4, 1.7 and 2.0 mm dia) prepared with the 40% of crude protein and 6% of lipid content. The fish were fed to apparent satiation twice daily (10:00 and 16:00 hours) during the 6-week feeding trial. The growth performance and feed intake of snubnose pompano was assessed at the end of the experiment.

There was significant difference ($P<0.05$) in weight gain percentage (WG%), specific growth rate (SGR), daily growth co-efficient (DGC) and average daily growth (ADG) among the treatments. Higher weight gain of 183.8% was witnessed in 32C treatment and the least weight gain of 162.66% was observed in 29C group. Similarly, higher SGR was noticed in 32C group and lower SGR was recorded in 29C. Similar trend was observed for DGC and ADG. There was significant difference ($P<0.05$) in feed conversion ratio (FCR), protein efficiency ratio (PER) and feed efficiency ratio (FER) among the treatments. Better FCR and PER of 1:1.50 and 1.08 respectively was observed in 32C treatment and the poor FCR and PER was recorded in 33C treatment. In case of FER higher values observed in 31C and 32C treatment group and lower values were witnessed in 29C and 33C treatments. Maximum survival percentage was observed at 30C treatment. Best growth performance in terms of WG% and SGR% and feed utilization in terms of FCR and PER was noticed at 32$^{O}$C water temperature. Beyond 32$^{O}$C of water temperature the growth, survival and feed utilization got declined. The result of this study reveals that snubnose pompano, *Trachinotus blochii* can be reared up to 32$^{O}$C without any changes in growth, survival and feed utilization.

Theme 6

# Livelihood, economics and trade

mbai-mecos 3

# Implementing the SSF guidelines at the national and subnational levels: Challenges and opportunities

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Marine and inland fisheries in India employ millions of women along the entire value chain, particularly in the pre- and post-harvest sub-sectors 70 percent of those engaged in post-harvest activities are women. Women's contributions are crucial for the management and sustainability of the sector, which need to be supported and enhanced. Recognizing this, India's 2017 National Policy on Marine Fisheries (NPMF) and 2018 Draft National Policy on Inland Fisheries and Aquaculture (NIFAP), both provide guidance for mainstreaming gender equity in inland and marine fisheries and aquaculture value chains. The policies envision increasing participation of women in decision making; strengthening women's associations and cooperatives; providing financial support schemes for women; improving working conditions for women along the fisheries value chain; and empowering women's leadership capacities.

The 2014 SSF Guidelines-endorsed by the Thirty-first Session of the Committee on Fisheries (COFI) in June 2014 were guided by the principle of gender equality and equity. Recognizing the need for the holistic development of fishing communities, especially in relation to fisheries management and development, the Guidelines recommend integrating gender mainstreaming into all small-scale fisheries development strategies.

Enhance the capacities of women fishworkers for the mainstreaming of gender into fisheries policy and legislation–Conduct a gender analysis of fisheries budget allocations and schemes and the socioeconomic indicators of fishing communities–Recommend action points for the implementation of NPMF 2017 and Draft NIFAP 2018, from a gender perspective–Facilitate exchange of knowledge between diverse women fishworker representatives and to develop a national platform for women in fisheries

# Role of Fishing Community Organisations in Fisheries Management in India

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Today, quite often, the discussion on fishermen participation in fisheries management is talked of as if it were a new concept. It is also seen as something that outsiders (including the fisheries department) are introducing/ promoting as a result of their progressive thinking and wisdom. This is, of course, just a delusion. This paper is about the role played by fishermen and their community organisations in the past and at present. In particular, it looks at the Indian context and discusses the roles that such organisation play in India and their future roles.

## Emergence of the nation state and the decline of community governance

Historically, the world over, marine fisheries were governed almost entirely by local fishing communities. However, the emergence of the modern nation state in Western Europe in the 16th Century onwards in conjunction with a new form of economic system—capitalism—resulted in the break down of all traditional production systems and the emergence of new industrial modes of production. These changes started impacting the fisheries sector from second half of the 19th century and showed that the once "inexhaustible" natural resource, is actually finite and can be degraded by enhanced technology and fleet enlargement. Fisheries science and fisheries management emerged in this scenario in Western Europe and North America, mostly in temperate waters under conditions of limited numbers of species with large stocks.

The nation state gradually took over fisheries management responsibilities and brought fisheries under its control. This became much stronger after World War II, when fisheries expanded in an unprecedented manner. However, the role of the state in fisheries management were conditioned by the development of the post-war "welfare state" system with its wide based social security schemes like employment insurance and unemployment doles. Since the welfare state systems were for the population as a whole and relevant to all sectors of the economy, the discipline of fisheries management, as developed in the West, is largely silent on issues like who should fish, labour vs capital intensity of production, who should benefit, etc. Unfortunately, adequate modifications in fisheries management theory have not been made for the tropics and developing countries. It is arguable that mere modifications are inadequate and radical rethinking is required.

## India: Caste and fishing community organisations

In India, the traditional fishing communities on the coast are organised into caste groups specialising in marine fishing. An understanding of the caste system and the position of the marine fishermen in Indian society is necessary to understand their past and present. Though considered a caste group, the fishing community is closer to tribes in their internal structure and self-governance practices. However, the commercial nature of fisheries that requires regular exchange of fish for other food and essentials with the Agrarian castes, has brought the fishermen into the framework of the caste system, even if they do not fit the traditional caste paradigm.

Till the late 1960s, fisheries management on the

Indian coast was almost entirely the preserve of traditional community organisations. These organisations come in two or three formats across the coast depending on proximity of settlement and landing centre and the links between religious, social and economic (livelihood) governance. The variations across the Indian coast are explained in this paper. These community organisations managed/ governed fisheries in different ways. Even if none of the management measures could be considered as stock management in the modern sense, they had many elements of management that we can recognise and appreciate. These included regulations governing resource access (who can fish), control over competition (who gets first priority to shoals), fishing gear regulations, controls over fish landing and landing centres, sharing system between owners and crew, migration, etc. Noteworthy is that there are many instances of traditional bans on fishing gears and "fishing holidays". These organisations also levied their own "taxes" to sustain themselves and provide a number of services to the community. They also had great sanctioning power to enforce their decisions.

## Mechanisation and the split in the community

From the mid-1970s, these organisations faced a serious threat to their hegemony due to the introduction of mechanised fishing, especially trawling, by the Fisheries Departments. This introduced a major differential in scale and fishing power on the one hand and brought in outsiders into the sector, on the other. With the new mechanised boats operating from new fishing harbours/landing centres under Govt control (and hence outside the control of the Community), the traditional institutions had no control over the new boats and their owners. Eventually, this "rouge" sector grew and an elite from within the community joined the ranks of boat owners. This split the community in many states on the basis of "mechanised" and "traditional" sub sectors. The traditional institutions, with some exceptions, lost control over the "mechanised" group, while retaining control over the "traditional" group.

## Govt take over of fisheries management

It is in this context, faced with a series of conflicts across coast, that the state Govts, prompted by the Central Govt, went in for Marine Fishing Regulation Acts to manage fisheries, with the stated intent of protecting small scale fishermen (aka traditional fishermen), protecting marine resources and "ensuring law and order in the sea". Legally, this meant that the Govt was in charge the sea and the traditional community organisations did not have any formal power. However, the traditional sector, which welcomed the changes as the new law was meant to protect them, continued to operate as before with their traditional organisations continuing to control traditional/small scale fishing activities.

However, the state Govts were not very effective in curbing the mechanised sector and the marginalisation of small-scale fisheries continued without pause. Meanwhile new technological options became available for small scale fishermen with out board motors getting introduced in the 1980s through market forces supported by state subsidies. This triggered the next wave of changes that took place in different states over the next two decades or so.

## More technological changes and further decline of traditional governance

The small-scale sector got motorised in stages with significant increases in its area of operation. New fishing methods making use of the motors also emerged. If some of the traditional gears like gill nets, bag nets and lines increased in scale, new active gears like ring seines and mini trawls became popular in different parts of the coast. The small-scale sector, who impact on resources was low, has also started adding to the stress on the resources.

The traditional organisations have been active through this period of small-scale fishery expansion. They had fought many of the changes like introduction of ring seines and got them banned by the Govt. We find the curious phenomenon of village level traditional organisations continuing to be strong at village level but unable to bring change at the larger level due to a split inside the larger community on the issue of new fishing gear. Organisations in villages that have adopted the new gear do not see eye to eye with those still opposing these gears. The consensus required across the coast to bring uniform rules is lacking. Strong locally, but ineffective at the scale where decisions have to be taken.

## Status of Govt management of fisheries

Inaugurated in 1980, the Govt regulations took nearly 25 years to cover the entire coast due to the sluggishness of many states. We now can boast of a system for vessel registration, gear regulations, area and time restrictions and finally a large-scale ban on mechanised fishing activities for two months every year. However, implementation remains weak. Since the introduction of the Act and the various regulations, the fishing capacity and effort have continued to rise with most resources on the shelf being fished to the full potential, if not more. The absence of capacity control and prevalence of de-facto "open access" despite laws and regulations, has led to cut throat competition in the sea between fleets and within fleets.

With fishing expanding beyond 12 nautical miles (which are the limits of the state Govt's jurisdiction), the EEZ has emerged as an unregulated area. At least three attempts were made to bring in a central legislation for the EEZ, but failed. Now a serious attempt has been launched again and this time the legislation is likely to go through as India is under severe international pressure to do so, both from international bodies and market forces.

The failure of state regulations are quite obvious. Many of the resources are stressed and a few have declined. More importantly, the constant scaling up has led to great inequity in access to resources with the more powerful units grabbing a disproportionate share of the catches. This is marginalising an already struggling small scale sector. The situation calls for serious action that will reduce fishing capacity, especially in the mechanised sector using active gears and to increase the share of the small-scale sector in the catches.

## Co-Management and the future of fisheries management in India

Co-management of resources, with Govt and fishermen organisations coming together, has now acquired a great deal of interest. Co-management pilots were started in TN and Kerala and both Govts have now declared policies that recognise co-management. This has set the stage to look closely at fishing community organisations and how they will participate in fisheries management.

## Fishing Community Organisations: Current Status

Fishing community organisations are present in various forms. The traditional community organisations are still quite strong in most states, but as discussed above, are not able to work on a scale to bring in the necessary controls. Still, they remain the most relevant in terms of representation of fisher interests and effective control over at least fishermen in their respective localities.

Mechanised boats are organised into associations at both harbour level and higher levels. They negotiate with both the Govt and small-scale fishermen, on behalf of their members. Many of them have significant political clout.

Cooperatives are present across the coast, but operate only as conduits for Govt subsidies, though with notable exceptions. They are mostly artificial entities with very little ownership among fishermen.

Independent fishermen organisations that fight for fishermen rights are also active on many issues related to fisheries and fisheries management.

Women's organisations have also come up across the coast to undertake a number of activities for the improvement of the fishing community.

## Future course

The power of the fishing community has to be harnessed to improve the lot of the community and bring effective fisheries management. This requires a proper understanding of these organisations and the role they currently play as well as their potential in the future. The paper provides an analysis of these organisations and suggestions for the future.

# Marine Ecosystems – Are economists just bystanders?

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In the world of ecosystems research, economists and social scientists are normally considered to have a non-core role to play in the context of sustainability and climate change. The focus in this area of scientific endeavour is largely on the biological aspects and probably rightly so. However, often these efforts overlook the fact that ecosystem sustainability cannot be achieved by only seeking solutions from an ecological or environmental perspective. These solutions have to be economically and socially compatible otherwise they would not succeed in fulfilling their aims. This caveat is widely accepted even though the dialogue between ecological science and economics may still be at a nascent stage.

There are different ways in which economists approach solutions — some of these are market-based and some are command and control in nature. A third approach relies on community-based (or initiated) solutions. Each of these alternative pathways overlays an ecological system with set of management rules. In the simplest instance this could a demand and supply issue with price being the mediating factor assuming that we have well performing markets. However, we do know that when it comes to natural resources markets do fail to equilibrate demand and supply — often because markets do not exist, and when they do exist, they are not reflective of true costs and prices. We understand that is the true social cost of a resource is higher than the market price then there would be over-extraction. In the absence of a clearly defined market, users treat the price as zero and mine the resource beyond sustainable limits.

This is where policy of command and control comes in. Regulatory processes tend to then limit extortion but not necessarily to optimal levels as policies in such instances are typically knee-jerk reactions of difficult compromises between strong lobby groups.

This is where economists could and do play a useful role. Economists has developed tools that allow us to project the true social value of a resource, even when markets do not exist. By this I am referring to the increasingly rich literature on valuation. Such estimates have great utility for policy and decision-makers. However, valuation exercises need to be very carefully done so that there are no gross over or under-estimates of resource values otherwise they would lead to inefficient outcomes. Valuation studies are broadly categorised into two groups – revealed preference methods and stated preference methods. The stated preference method arrives at values by constructing pseudo markets while the revealed preference methods use alternative behavioural information to construct values of a resource. Sensitive valuation exercise must have 3 goals: efficiency, fairness and sustainability.

One of the early estimates of the global value of ecosystem services by Costanza *et al.* (1997) estimated the average ecosystem services from marine biomes (including open ocean and coastal) to be \$ 577/ha/yr (in 1994 \$ PPP terms) with a total flow value of \$ 20.9 trillion/yr (in 1994 \$ PPP terms). These results were controversial but they did trigger a large debate. In a re-assessment by Costanza *et al.* (2014) the estimates for average ecosystem services from marine biomes was \$ 1368/ha/yr (in 2011 at 2007 \$ PPP terms) with a total flow value of \$ 49.7 trillion/yr (in 2011 at 2007 \$ PPP terms). This is nearly the double of the estimate in 1997 (after adjustment for prices was \$ 28.9 trillion/yr in 2007 \$ PPP terms).

There is a large data gap in the ecosystem valuation literature in India and more so in marine ecosystems. The Green Indian States Trust had initiated commissioned a set of studies and there are 6 of these that are published on their website https://www.gistindia.org/publications). But none of these are relate to marine and coastal ecosystem valuation. One assessment that was attempted to fill this gap is Kumar *et al.* (2016).

The largest number of studies in valuation focus on estimating provisional services as they are the easiest to estimate. Kumar *et al.* (2016) found the total value of the provisioning services of marine and coastal ecosystems to be Rs. 383 billion, regulating services as Rs. 655 billion, recreational services as Rs. 453 billion totalling to approximately Rs. 1.5 trillion. This was about 3.2% of the Net National Product (NNP) in the assessment year to 2012-13. These estimates were an underestimate as all services were not part of the valuation exercise. Further, the consumer surplus value was not included in many of the components. Therefore, with refinement of method and coverage better estimates could be arrived at.

The study did highlight that provisioning services which is what is most commonly valued was estimated to account for 26 percent of the total marine ecosystem services in India. Regulating and recreational services accounted for 44 percent 30 percent (respectively) of the total value. There is a need for more research in this area.

Table 1: Value of Marine and Coastal Ecosystems in India

| S. No. | Service Valued | Value Range | | Average Value |
|---|---|---|---|---|
| | | Min. | Max. | |
| I. | **Provisioning services** | | | |
| 1 | Marine Fisheries | - | - | 294.48 |
| 2 | Seaweeds | - | - | 0.09 |
| 3 | Coastal Minerals | - | - | 12.47 |
| 4 | Coastal Salt | - | - | 12.4 |
| 5 | Seawater Desalination | 18.01 | 22.21 | 20.11 |
| 6 | Seawater – Industrial Cooling | 2.58 | 4.76 | 3.67 |
| 7 | Coastal Shipping | 15.88 | 63.8 | 39.84 |
| | Total Provisioning | - | - | 383.06 |
| II. | **Regulating services** | | | |
| 8 | Coastal Protection (Mangroves) | 560.38 | 754.04 | 653.98 |
| 9 | Carbon Sequestration (Mangroves) | 0.76 | 1.65 | 1.21 |
| 10 | Carbon Sequestration (Seagrasses) | 0.01 | 0.04 | 0.03 |
| | Total Regulating | 561.16 | 755.73 | 655.21 |
| III. | **Recreational services** | | | |
| 11 | Coastal Recreation | | – | 452.92 |
| | Total Recreational | | - | 452.92 |
| | **Grand total** | | | 1,491.19 |

Source: http://www.mse.ac.in/wp-content/uploads/2016/10/Monograph-35.pdf

# Impact of Titili cyclone on marine fisheries of Andhra Pradesh

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Cyclones have become a recurrent feature in the Indian sub-continent. In India, the east coast is one of the six most cyclone prone areas in the World. Due to the erratic monsoon the fishers aren't able to adapt/prepare and become aware on these losses.

Srikakulam district is located in the extreme northeastern part of Andhra Pradesh. The district has the longest coastline (about 193 km) in the state. Fishing continues as a main occupation of the coastal people of Srikakulam district. However, problems like seasonality of landings and uncertainty of prices in this sector creates vulnerability among the fishers affecting their livelihood. The recent *titili* cyclone during 11th October 2018 made fisher's life even more miserable. The present study in general is meant to understand the effect of *titili* cyclone on the marine fisheries sector of Srikakulam district of Andhra Pradesh and to develop a future rehabilitation plan for the well-being of this sector.

The study is analytical and descriptive in nature. The universe of the study includes the fishermen respondents from the major cyclone affected areas of Srikakulam district. The primary data from 60 fishermen from the different fishing villages such as Isakapalem, Ramayyapatnam, Battigalluru and Sompeta who were affected by the cyclone are collected using random sampling method. Secondary data from related publications and Real Time Governance website of Andhra Pradesh were also used in the study.

It was found that, 53 per cent of the respondents have more than 25 years of experience in fishing, and 47 per cent of the fishermen have experience between 10 and 25 years. On an average 86 per cent of the respondents go for fishing daily, 13 per cent go for fishing on alternate days and only one per cent of the respondents go for fishing weekly twice.

Thirty five per cent of the respondents were aware of cyclone beforehand. The respondents were highly affected by the cyclone and most of them were victims of such a huge cyclone for the first time. The Governmental support provided isn't enough for compensating such losses. The local committees should be sensitized for the different adaptation and mitigation options. There is a need to provide customized training programmes to increase the awareness towards these natural disasters. Based on the survey conducted and the discussions had with the affected people, the following measures are suggested for mitigating the impact of cyclones in future.

- Information sharing through mobile
- Better governmental support in rescue operations
- Better weather information dissemination mechanisms
- Mapping of cyclone prone areas in advance
- Engaging Local Self Governance (LSG) in information sharing
- Impart training to fishers for carrying rescue operations
- Strengthen inter-governmental linkages
- Awareness campaigns for confronting cyclone

Cyclones and floods are natural disasters and are now a days a risk (as they are predictable with a reasonable degree of certainty) and not an uncertainty. Hence it is wise to plan for mitigating the impacts of such disasters beforehand than waiting for the disaster to happen and blaming the governance systems.

# Farmers innovation and adoption of Mariculture technologies – A case from Ramanathapuram district of Tamil Nadu

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Marine fisheries sector in Palk Bay and Gulf of Mannar region is witnessing overexploitation of trawling grounds, declining catches and consequent reduction in profit. In such scenario, diversified livelihood options should be provided to the fishers. Moreover in future years the additional marine fish requirement has to be met by Mariculture. The sustainable farming methods which are being adopted by fishermen groups in Ramanathapuram district are cobia farming in sea cages, marine ornamental fish seed rearing, seaweed farming, pen farming of milkfish, lobster fattening in pen/cages and Integrated Multi Trophic Aquaculture (IMTA). A study was conducted to assess the extent of adoption and impact of those farming methods on the livelihood of fishers. It was found that the benefit cost ratio (BCR) for all the farming methods were above 1.0, which indicates the profitability of the enterprises. Moreover, an additional employment of 100 to 200 man-days per annum per unit of those farming methods could be gained by the fishers. Farmers innovations or modifications of certain technologies to suit their local conditions has also been documented. The adoption of mariculture technologies by the fishers proved that all are viable diversified livelihood options to the fisherfolk. Attractive State and Central government schemes are essential for wider adoption. It is anticipated that the popularization of mariculture technologies in the areas like Palk Bay and Gulf of Mannar region of Tamil Nadu can reduce the fishing pressure and can substantially increase the seafood production.

# Scientific protocols followed to commercialise a non-conventional crab from Karnataka coast, focussing on the perspective of improvement of nutritional status and livelihood avenues

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With the advent of time, marine and coastal zones and comprising of 70% of the globe is considered as the potential source of healthy nutrition for increasing world population. While considering a non conventional species for commercial exploitation, there are some prerequisites to be followed, to popularise its consumption and its sustainable utilisation. Ascertaining the taxonomic status of the species, awareness of its commercial use elsewhere, ascertaining its availability in space and time for commercial exploitation, information in its meat content and its nutritional status, further by envisaging its commercial exploitation, understanding biological and stock related information will help in its sustainable exploitation. Since the conventional fishery resources are reported to be overexploited in most of the Oceans, efforts are focussed to bring more non- conventional resources into food basket by identifying its availability in space and time and also by identifying its nutritional advantages.

In the present study, scientific attempts are made to explore the commercial exploitation prospects and investigate nutritional advantages of non-conventional crab *Charybdis lucifera* from Karnataka coast, to encourage its exploitation and utilisation. As an awareness to enable the acceptance of the crab as the food source, the utilisation of the crab from other parts of the country were reviewed and it was reported that in many parts of the world including east coast of India the species is being consumed by local community. Taxonomical identity of the species was ascertained by following classic taxonomic tools in identification of brachyuran crabs. *C. lucifera* is found widely distributed along Karnataka coast, up to 30m depth from the shore. These crabs are seen as a regular catch in trawlers operating single day operations with an average estimated annual landing of 45t during 2015-2016. The size range observed were 21 mm to 90 mm weighing 5 to 165g, and crabs weighing 100 to 140g dominated the catch. As it is established that it is an edible variety in many parts of the country, studies on meat content, proximate composition, mineral content, amino acid profiles and fatty acid profiles were carried out which were found to be comparable and many times superior to the conventional edible crab species from the coast, *Portunus pelagicus* and *P. sanguinolentus*. Percentage of dry matter ranged from 11 to 16% with crude protein ranging from 79 to 80%, crude fat 3 to 5% of the dry weight. Amino acid and fatty acid profile of the crab also were investigated and it is found the C. lucifera contained mono unsaturated fatty acid, Oleic acid and saturated fatty acid Palmitic acid in considerably high quantity to supplement the nutritional deficiency issues in coastal population.

For ensuring sustainable exploitation of a species, it is the responsibility of the researcher to ensure stock status and MSY. In present analytical stock assessment methods, length frequency data derived from the field is used to convert the length observation to weight for biomass estimation. Length-weight relation for males and females were derived as $0.221706*CW^{3.04}$ and $0.204062*CW^{2.90}$ respectively indicating that males were heavier than females and the difference in growth was significant at 5% level. Knowledge on the natural diet of the species is important to understand its trophic interactions in the ecosystem and further for developing aquaculture techniques. Gut content studies on 293 crabs of various size groups showed that crustacean remains (30.63%) were dominant food items followed by algal matter (20.89%). Reproductive parameters such as size at first maturity, spawning frequency, fecundity and recruitment are of great value in fishery prediction, formulation of conservation measures and also developing aquaculture programs for the species. In *C.lucifera*, male and female were found in almost equal proportions (55:45) and the species was found to breed throughout the year. The size at first maturity (50%) for, *C. lucifera* was estimated at 35 mm.

Present study recommend that *C. lucifera,* with its wide distribution in space and time, high meat content and nutritional supremacy in terms of its minerals, amino acid and fatty acid profiles offers great potential for commercial exploitation as human food and the results of biological studies will form a baseline for its stock assessment and sustainable fishery in future.

# Kadal osai –A communication network for fishermen community

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Our Community Radio started by Nesakkarangal Charitable Trust for Fishermen's empowerment and management. In India we are the only exclusive CR operating for fishermen and their welfare. Our 24 hours service provides information on daily Weather report, Fish rate (auction), Petrol, diesel rate, fishermen token from fishery, remainders on life jacket to boat as special elements. Apart from this daily routine we work in areas like health, hygiene, food, livelihood security, child education, and alternative sustainability methods, potential fishing zones through INCOIS social issues related to fishermen in their day to day life are also addressed. A show named Samuthiram Pazhagu (know your sea) speaks mainly about sea conservation, importance of sea animals like dugongs, sea turtles, sea horses, sea cucumbers and also about sea grass, coral reefs, mangrove forest, fish varieties etc.

Kadal Osai is purely for the local population and by the local people. The station focuses on motivating people by joining hands with projects from UNICEF (Child marriage & child education), SMART (Sweep activity on 100% voting by ECI), Poshan Abhiyan, Water conservation and SDG 6, 11, 13, 14. That is clean water and sanitisation, Sustainable cities and communities, climate action and life below water.

Our content providers are CMFRI, Tamil Nadu Marine police, Coast Guards, Wild life Institute of India, INS Parundu (Indian naval air station) and District administration on Social justice and laws & ICDS – Women welfare.

Our trust bears all expenditure for resources, manpower and running cost. We empower 10 local youths with employment and also skill development training for women.

Importance of such community FM's in coastal areas – Fishermen are usually brave since they face the hard sea on daily basis from the day they were born. It's hard to make them believe that Tides and waves are can risk their life, trawlers are harmful, open defecation near sea shore spoils quality of fish, throwing garbage on to the sea is bad and many, since they are doing these for ages. And also information on weather, power cut (especially for ice-plant), token (from fisheries) and fish rate are very useful for them.

Our future plan is to provide an undisturbed radio service to their boats with VHF.

# Access and benefit sharing among the stakeholders for ten major fishery resources in Karnataka

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The technological advances in fishing gears and crafts enabled exploitation of fish by larger mechanised vessels and has resulted in limited access and reduced benefit sharing to the small scale fishing communities in the developing countries. In the present study, the access and benefit sharing among the stakeholders for ten major marine species/groups were studied. Fish species representing marketing linkages of all the beneficiaries involved in the marine fishing sector were selected for the study. The species selected for the study includes Indian oil sardine, Indian mackerel, narrow barred Spanish mackerel (Seer fish), tunas, pomfrets, ribbonfish, threadfin breams, lizardfish, rock cods, shrimps and squids. These ten species together forms more than 90% of total landings of Mangalore, Malpe and Karwar fish landing centres. Customized questionnaires designed were used to collect relevant information from a) fish landing centres (Mangalore, Malpe and Karwar) of Karnataka, b) fish markets (wholesale, retail, cycle vendors, scooter vendors, rickshaw vendors, etc.), c) fish cutting centres, d) fish processing plants, e) canning plants, f) *Surimi* plant and g) fish meal industries. Information such as details of boat owners, auctioneers, interstate traders, species and quantity of fish handled by them, total number of days of availability for different variety of fishes during peak season and lean season in an year, disposal/utilization pattern (in local markets, interstate transfer, industrial utilization, export, etc.), cost involved in washing fish, icing, packing, and transport were collected from the landing centres using the customized schedules prepared. Secondary data on species-wise landings of marine fishes for the year 2016 was obtained from the data bank of National Marine Fisheries Data Centre (NMFDC) of ICAR-Central Marine Fisheries Research Institute (ICAR-CMFRI). Using the data gathered from different stakeholders, the total profits (net benefit) earned by each category of stakeholders was calculated. The profit per person from the particular sector was calculated considering total number of people involved in each category.

In Mangalore, the maximum share of benefit was taken by processing plants (36.9%) followed by *Surimi* plants (24.3%), purse seine boat owners (11%), canning plants (10.7%), inter-state traders (7.4%), fish cutting centres (2.2%), trawl boat owners (2.1%), and wholesalers (1.7%). Other stakeholders such as retailers (0.8%), auto vendors (0.8%), gillnet boat owners (0.6%), fish meal plant owners (0.5%), drying yards (0.5%), two wheelers (0.3%), head loaders (0.2%) and traditional boat owners (0.05%) received less than 1% of benefit share. Similar to Mangalore landing centre, the maximum benefit share was received by processing plants (43.1%) at Malpe followed by canning plants (17.2%), *Surimi* plants (15.7%), purse seine boat owners (9.4%), interstate traders (8.1%), trawl boat owners (1.4%), Fish cutting centres (1.2%) and wholesalers (1.2%). Other stakeholders such as gillnet owners (0.7%), retailers (0.6%), auto vendors (0.5%), fish meal plant owners (0.2%), drying yards (0.2%), two wheelers (0.2%), head loaders (0.1%) and traditional boat owners (0.1%) received less than 1% share of benefit.

In Karwar, the maximum share of benefit was received by interstate traders (26.4%), followed by fish meal plants (18%), purse seine boat owners (17%), processing plants (8.5%), *Surimi* plants (7.8%), fish cutting centres (6.4%), trawl boat owners and wholesalers (5.3%), auto vendors (4.4%), two wheelers (2.7%) and retailers (1.7%). Other stakeholders such as head loaders (0.9%), gillnet boat owners (0.5%), fish drying yards (0.5%) and traditional indigenous boat owners (0.1%) received less than 1% of the total benefit share.

The study clearly indicated that the maximum access and benefit share was received by the processing plants, *Surimi* plants, canning plants, interstate traders, purse seine boat owners and fish cutting centres from all the three landing centres studied. In contrast, the retailers, auto vendors, head loaders, two wheeler merchants, gillnet boat owners, drying yards and traditional boat owners received less than 1% of the benefit share in all the three landing centres. Further, the study clearly established that there is limited access and benefit share to the small scale traders and traditional small scale fishers. The information provided here forms a baseline data for the policy makers and managers in formulating management guidelines and also for the government to plan for schemes to provide incentives to the small scale traders and traditional fishermen.

# Upliftment of scheduled tribes and scheduled castes of India through implementation of Mariculture technologies of ICAR-CMFRI

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The various standardized mariculture technologies developed by ICAR CMFRI such as cage farming for fin and shell fishes, marine ornamental fish breeding and its culture, Oyster and sea weed farming, crab and lobster fattening and pond fish culture, were extended to Scheduled Caste and Scheduled Tribe (SC/ST) communities all along Indian coasts under the Tribal Sub Plan (TSP) Project and Scheduled Caste Sub Plan (SCSP) Projects of Government of India. The beneficiaries for the projects in each location were selected in consultation with line departments like Tribal Extension office, Scheduled Caste Development Office, Gram panchayat/ Municipality, Village Office and Agriculture Office. The selected beneficiaries were given hands on training at their respective location/site on the above technologies to empower them to undertake the work earmarked. The farmers were supplied with all infrastructure facilities like GI cages, HDPE cages, nets, seed, feed, other facilities like rearing fish units, glass aquaria, aeration pumps, adults pair of broodstocks, fish seeds, etc. free of cost. The sidi tribes from Gujarat were given training on scuba diving and also supplied with scuba diving kits for management of cages launched in seas. The farmers who are involved in cage farming were supplied with life jackets and buoy for ensuring their safety. The cage farming was established at various centers and location specific species were selected. The culture of finfishes such as pompano (*Trachinotus blochii, Trachinotus mookalee*), Cobia (*Rachycentron canadum*), Grouper (*Epinephelus tauvina*), Mullet (*Mugil cephalus*), Mangrove Red snapper (*Lutjanus argentimaculatus*), Seabass (*Lates calcarifer*) and Pearl Spot (*Etroplus suratensis*) were undertaken at farmers field as a livelihood option. Shell fishes such as Lobster (*Panulirus homarus*), Crab (*Scylla serrate*) were also undertaken for cage farming. A total of 30 cages were launched all over India for the social and economic upliftment of SC/ST communities. For oyster farming, the suitable sites at Mulki estuary Mangalore and Pulloot, Kerala at Trissur were selected. The farmers were given hands on training and established oyster farming units in their respective states. Apart from these, seaweed farming was also undertaken at Mandapam Regional centre of CMFRI. The beneficiaries were supplied with farming materials undertaking farming as an alternate livelihood option. The marine ornamental fish breeding technologies developed by CMFRI were also extended to these communities, and breeding and seed production units were established, which are operated by Women Self Help Groups. For effective management of the programme at each centres Self Help Group consisting 5 to 10 members were formed and each were assigned group names and these were registered in respective panchayat. All the culture activities were monitored every 15 days till harvest. The implementation of projects among SC/ST communities revealed that the Mariculture technologies developed by ICAR-CMFRI have been well accepted, and it serves as a livelihood option for these communities. SC/ST benefitted under these projects are Sidi Tribes of Gujarat, Yenadi tribes of Andrapradesh, Bhoomija of Odisha, Pallan communities of Tamilnadu, Ulladan, paniyan, Pulaya, Thandan and Mavilan of Kerala and various ST communities of Maharashtra. Through cage farming, the farmers earned 2.5 to 3.5 Lakhs/cage/culture periods depending upon species selected. In ornamental fish culture a revenue of 75000 to 1.0 Lakh per year, and for seaweeds farming 1.2 to 1.5 lakhs per culture period, Rs. 40,000 to 50,000/ unit for crab fattening, Rs. 80,000/-per cycle for Lobster, 50000-1.0 Lakh for pond culture of mullets, Rs.50000 to 1.0 Lakh/ Oyster farming unit can be obtained in 8 month culture period. Since all expenditure for the culture operation is met by CMFRI through the TSP and SCSP projects, the revenue earned through culture were considered as their profit that helped in their economic and social upliftment all over India.

# Fluctuations in Oil sardine landings and implications on the marine fish economy and fishers livelihoods in Kerala

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The Indian oilsardine, *Sardinella longiceps Valencienne* is a significant contributor to the marine fisheries economy of Kerala state. The decline in oil sardine landings in the state in recent years is a critical issue of concern for the sustainable exploitation of the resource. The catch decline will have serious implications on the marine fish economy as well as livelihood security of small scale fishers. The economic impacts of the decline in oil sardine landings on gross value realized at landing centre and retail levels, inflation in domestic markets, livelihood security of traditional fishers and fish meal industry in the state were analysed during 2000-2018 period. The oil sardine catch declined from 2.41 lakh t in 2000 to 77,093 t in 2018 whereas the retail price increased from ₹25/kg to ₹120/kg during this period. The annual average decline in oilsardine landings in Kerala was 19.82% whereas the decline in gross value at retail market level was 12.18% during 2010-18 period. The inflationary pressure on domestic consumers was very high during 2010-2018 period. The fluctuations in gross value was more at landing centres (point of first sales) when compared to retail level indicating the prevalence of unstable prices to the fisher folk.

# Gender mainstreaming and impact of SHGs in Indian fisheries sector: A brief portrayal

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A study was made on the impact of 1000 selected 'Self Help Groups' (SHGs) in gender mainstreaming in marine fisheries sector. Their level of performance and extent of empowerment was assessed through appropriate indices of measurement based on data from SHGs of 28 different fishery based micro enterprises from 5 maritime states of India such as Kerala, Karnataka, Tamil Nadu, Andhra Pradesh and Odisha. The gender analysis and economic feasibility analysis based on personal interview and focus group interaction meetings with members of SHGs were undertaken. The male and female counterparts of the families of respondents were separately interviewed to assess the gender mainstreaming impact in terms of equity and equality to access and control over the resources, participation profile, decision making, gender need analysis etc. Analysis of data was essentially done with descriptive statistics such as mean, frequency, percentages, chi-square etc. and there was no significant difference in the response of men and women counterparts in many of the activities of the enterprises, however, differential gender response was observed between the selected states. As practical extension part, organized 250 fisherfolk interaction meetings and imparted 100 Entrepreneurial Capacity Building (ECB) Training programmes for the SHGs on the identified micro enterprises by HRD intervention programmes.

The major micro enterprises of the SHGs studied were cage culture, bivalve farming, fish aggregating devices, Chinese dip net, clam processing, fertifish, fish amino acid, fish drying, seaweed culture, aqua tourism, seafood kitchen, value addition, fish vending, fish marketing, ornamental fish, ready to eat and cook items, fish feed, aquaponics etc. Economic Feasibility analysis were done for 25 fishery based micro enterprises accomplished by SHGs, and 25 allied sector microenterprises, and developed Business Plans of the microenterprises representing the indicative economics projecting the break even and payback period of micro-enterprises. The main constraints faced by the women entrepreneurs while doing the different income generating activities related to fisheries were analysed for making strategic recommendations. An exclusive data base on Scheduled Caste beneficiaries based on the Economic feasibility analysis and preference ranking of appropriate fishery based microenterprises was generated and beneficiaries were identified for undertaking 8 entrepreneurial ventures for 100 beneficiaries of various SHGs of SC fisherfolk. The enterprises identified were cage culture, fish seed production units, fish fertilizer, fish processing, ready-to cook dry fish and ready to cook frozen fish etc. which are being implemented systematically. Documented 100 success cases on ECB of SHGs with special reference to gender perspective. Brought out 25 video documentaries as Gender Mainstreaming series on Impact of SHGs in Marine Fisheries Sector, one compilation on Gender Mainstreaming and Impact of SHGs and one Interactive Multimedia as ICT Module on Gender Mainstreaming and SHGs developed as a cyber-extension package. The success case studies elucidated can be used as a model for promoting group action and as a practical manual for mobilizing SHGs in any key areas on a sustainable basis.

# Pedagogic and pragmatic dimensions of vocational education system in fisheries and perceived employability

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Development of human resource is critical for sustaining, diversifying and realizing the potentials of any sector in agriculture. Fisheries sector is projected as a potential area which offers numerous employment-oriented avenues due to fast pace of transformation. Therefore, a huge demand for knowledgeable and skilled human resource is to develop standard products and to deliver services in the sector. Vocational education in this sector is considered as the basic foundation for the development of the skilled workforce in it. Though vocational fisheries education is projected as potential employment supportive initiative, retrospective information regarding the scale of employability which it offers, validated research data on status of its present attainments in employment generation and information on the probable KST gaps in the existing teaching system are very skimpy. Similarly, there is a lack of educational policy-oriented information of the human resource turn out in terms of employability commensurate with the changing demands of the industry. The present study involved 120 vocational aquaculture students and it provides an insight in to the projective work profile transition from the parent to child by using the latent profile analysis. An attempt was made to identify the motivational factors to go for a vocational education and to assess the status of vocational education system in the perspective of molding employability among students. An estimation of proficiency level with respect to employability and identification of competency training needs were carried out through Knowledge-Skill-Trait gaps (KSTG) model proposed in the study.

# Fisher as co-author- reflections on participatory research in fisheries social science

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This paper analyses the implications of taking fishers as an active epistemological partner in the social science knowledge generation process. The transformation of fisher as a source of information has been conventionally followed and deemed as a participatory model in fisheries social science, to that of a knowledge generator throws up some interesting methodological opportunities and questions. The advantages and disadvantages of this methodological innovation, including the replicability of the co-authorship reciprocity model, are discussed using a first of its kind real life example from India. The perceived stakeholder empowerment, as per the case study, was found to have a nuanced interpretation by the beach level peer group in terms of social identity, credibility, and social dissonance. The discourse has significance in the emerging co-governance scenario of the marine fisheries sector in Kerala.

# Profit share and bio-resource utilization in fish cutting sheds (FCS) in Karnataka

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Fish Cutting Sheds (FCS) is ancillary small scale pre-processing units which support major fish processing industries. These units are involved in the preprocessing (beheading, removal of scales and viscera, washing) of fishes, which becomes the raw material in canning and Surimi plants. Presently, in Karnataka there are 52 fish cutting shed located in Mangaluru, Malpe, Kundapur and Karwar. Customized schedules were prepared to collect data pertaining to fish species processed, quantity of different fish species purchased from fishing harbours, purchase price, days of operation in an year, quantity processed per day, cost of production, cost of final product, number of workers in the firm, labour cost and cost of ice from 14 FCS. Net benefit earned by FCS from each resource was calculated using the information collected on fixed and operational costs. The marketing channels for the fishes which are handled by the FCS were collected from the selected fishing harbours (Mangalore, Malpeand Karwar). Primary data on utilization of various landed fishery resources by different stakeholders were also collected using the customized schedules. Based on this, total quantity of different fishes procured by FCS from selected harbours during 2016 was estimated based on total estimated fish landings data maintained in data bank of National Marine Fisheries Data Centre (NMFDC) of ICAR-Central Marine Fisheries Research Institute (ICAR-CMFRI).

The quantum of catch traded by different stakeholders was estimated based on landings data and catch share by various intermediaries. The analysis showed that threadfin breams were the major resource (42-43% of the total threadfin bream landings in Karnataka) processed by cutting sheds followed by Indian mackerel, lizard fishes, rock cods, ribbonfish and oil sardine. The processed threadfin breams, lizard fishes, rock cods and ribbonfishes were used by Surimi plants while Indian mackerel and oil sardines were taken by Canning plants. The processing charges varied from a minimum of INR 4 per Kg for Mackerel to a maximum of INR 8 per Kg for oil sardine. The maximum profit was obtained when the cutting sheds handled rock cods while the minimum profit was from oil sardines. From the socio-economic point of view, each cutting sheds provided part-time employment to nearly 100 fisher women and each woman earned Rs. 300 per day, which formed an additional income to their families during peak fishing season. These units have not only provided alternate livelihood to fisher-women but also helped the fish processing plants in obtaining partially processed raw materials, as some of the processing plants do not have sufficient space for handling huge quantities of raw fish.

# Need to relook at the gender dimension in small scale fisheries

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Of the 120 million people involved in fisheries in the world, about 90% are engaged in small scale fisheries. It is established that over 90% of all small scale fishers live in developing countries. This includes most coastal communities for whom fish had been a source of livelihood, family nutritional security and income. It is also acknowledged that 50% of small scale fish workers are women.

Gender equality is an important Sustainable Development Goal of the UN (SDG5). The SDG5 targeted ending all forms of discrimination against all women (and girl) and included a key point on 'ensuring equal rights to economic resources'.

The Voluntary Guidelines to Securing Sustainable Small-Scale fisheries in the Context of Food Security and Poverty Eradication is the first International instrument that stress on the small scale fisheries. The SSF Guidelines emphasizes the human rights approach to fisheries and gender equality is an important component in it. Women played important roles in small scale fisheries and were the key to almost all the pre- and post-harvest activities. They made and mended nets, sorted and marketed the catch and processed excess catch for long term economic and family use. Evidence shows that over time there has been systemic exclusion of women from the fisheries value chain as technology and economy took over. The transparency of the value chain is also low and this systemic exclusion are often ignored and considered 'normal' in line with the changes and with policy options disguised in terms like 'alternative employment opportunities.' Even in what can be considered organized industrial setups like the seafood processing, the transparency is low, because of the complexities and dynamics in the chain.

It is important to re-emphasize the importance and contribution of women to fisheries and explore how the guidelines can be used to count the women and make them matter.

# Beyond marine fishing: Drivers of diversified livelihood trajectories among fishing communities of Bengal, India

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Marine Fishers often engage in multiple income generating portfolios and in doing so, make best use of the ecosystem supplies and services that the coastline has to offer. The highly coupled human-natural systems translate in to an array of income earning opportunities, as was observed in East Medinipur district, of the Coastal State of Bengal. Apart from marine fishing, the bricolage of activities that fishers engage themselves range from dry fish making, net mending in the fisheries sector, raising of agricultural crops such as paddy, vegetables, betel vine as well as raising of dairy and livestock. The major idea underpinning the practice of diversified livelihoods are that, these activities aim to decimate the prevalence of activities which are deemed environmentally unsustainable by activities which are having lesser repercussions but at the same time bequeathing equivalent tradeoffs.

A total of 24 drivers of socio-personal, socio-psychological and socio-economic characteristics governing the diversification of livelihoods by marine fishers were delineated using Principal Component Analysis followed by Varimax rotation. The results revealed that, eight factors namely, Impact factor, Income factor, Social factor, Decision factor, Family structure, Psychological factor, Managerial Economic factor and Achievement factor influenced the adoption of diversified livelihoods. These factors account for 72.25 percent of the variance in the adoption of diversified portfolios by the marine fishers. Descriptive statistics revealed that, among the factors extracted, the decision factor had the maximum say and family structure the minimal say, in influencing fishers in the practice of diversified livelihoods.

# Molluscan dive fishery in Vellar estuary, Tamil Nadu

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Molluscs are a diverse group of fascinating animals which greatly differ in form and colour keeping the internal structure constant. Around 85000 extant species of molluscs are recognized worldwide today. They are both edible as well as non-edible. Most of the edible molluscs like mussels, squids, oysters, clam and cockle are consumed by the poor people along the east and west coast of India. In India, the Molluscs contribute vitally to the fishery sector, providing nutritious food to the local consumers and also adding income to the country through exports. It also provides employment opportunities for dependent communities in the coastal areas. In addition the dead shells and shell products are used for a variety of purposes including ornament making, manufacturing of lime and cement etc. In the Vellar estuary, fishers are engaged in dive fishing of molluscs in large scale almost round the year for domestic consumption and it is also being used as feed in shrimp farms. The income generated from this dive fishery is a major part of the livelihood of the fishers in this region. The present study attempts to describe the socio-economic conditions of the people involved in the molluscan dive fishery, documenting occupational hazards of the stakeholders and also mapping the molluscan resources in the Vellar River.

# Analysis of market demand and supply of bivalves in Tamil Nadu: A case study

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Considering the potential of bivalve availability and future or anticipated consumption and also the potential livelihood opportunities provided by bivalve capture/ farming, a study was proposed under Fisheries Management for Sustainable Livelihoods (FIMSUL)– II exclusively focusing on bivalve farming as a component. The study involves an assessment of the demand and market potential of edible oysters and green mussels in local and outside markets besides identifying suitable sites for bivalve farming and identifying suitable beneficiaries for carrying out the farming and develop supply chain for value addition and marketing. Two types of market surveys were conducted to estimate the demand and supply and to assess the potential.

The market survey for estimation of demand and supply of bivalves and to assess the consumers' perception about bivalves' consumption was carried out in 11 selected villages in Tamil Nadu and Puducherry, across 1,972 respondents. The analysis of the market demand survey revealed that very limited number of fishers go for clam fishing. Most of the respondents (85%) revealed that, the mussel production has decreased over the years. Among the fishers who go for clam fishing, about 60 per cent of them go based on the demand for clam and not on regular basis. Regarding the method of sales, only clam meat is popular compared to depurated meat. About 50 per cent of the fishers sell clams with shell only. Most of the respondents (87%) were aware of the medicinal value of the bivalves. About 60-70 per cent of the fishers consume mussel but most of them (76%) consume only occasionally. Most of the (about 85- 90%) respondents were not aware of any value addition to bivalves. The consumers also expressed that they had no health issues after eating mussels or clams.

The analysis of the consumers' perception of bivalves indicated that most of the consumers (91%) were aware that clam meat, mussels and oysters can be consumed and also aware (96% of the respondents) of the medicinal values of these bivalves. Most of them (96%) preferred to buy depurated meat to whole clam. Regarding the frequency of consumption, most of the consumers (99%) eat clam occasionally and all of them buy clams from fishers directly. The average quantity purchased for consumption ranged from 0.5 kg to 1.0 kg. Most of the consumers (82%) expressed that the availability of clams is not regular. The consumers expressed that they had no health issues after consuming mussels and about 55-60 per cent eat mussels in their locality. The consumers prepare "mussel gravy" (45-50%) from the mussels, about 30% consume clam curries and they are unaware of any other value added products like mussel soup or mussel pickle. The consumers expressed that they consume mussels regularly due to its taste (65 to 78% of the respondents), followed by low price (9%), availability (8%) and medicinal value (5%). They expressed the concern that mussels are not available in all the fish markets

The market potential was estimated by surveying the hotels and resorts in Chennai and Pondicherry. In the study area, 145 resorts and 82 hotels were surveyed in Chennai and Puducherry. The estimated market potential worked out to 131 tonnes per annum comprising 73 tonnes (55%) of oysters and 58 tonnes (45%) of mussels. The total demand for bivalves including all sections namely hotels, hatchery and domestic consumption worked out to 201 tonnes comprising 113 tonnes of oysters and 88 tonnes of mussels

The results indicate that, there is scope for improving the bivalves production through fish farming from these villages with adequate technical and financial support from the Government. Also there is scope to further increase the market potential of bivalves by increasing the awareness on the benefits of consumption of bivalves like mussels, clams and oysters in future. These can be achieved with the involvement of the agencies like Tamil Nadu Fish Development Corporation (TNFDC) by coordinating the marketing of the bivalves, linking the fishers and the market.

# Spatio - Temporal Analysis of Marine fish Valuation in India – Insights and Perspectives

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The present fish production in India is 13.7 million MT with a contribution of 3.49 million MT from marine sector and 10.21 million MT from inland sector. Amidst slump in landings, the valuation of fish considerably increased on account of the realization of higher prices, movement of fish from non-consumption areas to consumption areas, increased export earnings and augmented fish consumption. The valuation of fish depends on the place where it is caught (rural/urban coast), its size ranges (small/medium/large), season (peak/lean) and the quantum landed. In this connection, the present study on spatio- temporal analysis of marine fish valuation in India attempts to provide an insight into the trend in the fish price realization and marketing efficiency across the different coastal states and commercially important marine fish species using different statistical and econometric tools. The paper explored to decompose the valuation into the different constituent components like quantity and price effect. The paper also assesses to identify the different perspectives on fish landings, trade and consumption for the future. The paper portrays the development of Fish Market Price Information System (FMPIS) as a decision support tool to ensure the dissemination of fish price information for a highly efficient fish marketing system to ensure the fish availability for the people.

The landing data of fish were obtained from NMFDC, CMFRI. The study indicates that the valuation of fish has mostly increased due to the movement of fish from one state to other, which results in higher price realization. The prices of low value fish species have not been stable for several reasons and the prices varied depending on species, seasons and abundance of other fish and fishery products. The revenue are determined more by price effect rather than quantity effect. However it has to be cautioned on the context of fish movement quality is ignored and the self-sufficiency in fish food security in individual state is under question. The marketing efficiency varied across different species leading to poor fishermen share of the consumers rupee.

The current innumerable hassles in export of fish are also coupled with inefficient domestic marketing system, it is important to integrate domestic and international markets to ensure sustainability of fisheries trade. The different stakeholders (fishers, traders, consumers, exporters and policymakers) need to be made aware about the market and price of fishes for evolving efficient marketing systems and supporting infrastructure that would lead to better quality and prices. In order to ensure quality, legislation are required and the development of a Fish Market Price Information System (FMPIS) to act as a decision support system would ensure fish market and price information dissemination about availability, accessibility and affordability of fish. FMPIS enables different stakeholders mainly fishers in identifying target prices / markets; consumers with rational choices about fish availability and traders with inputs for better marketing efficiency. Moreover the fish market and price information system could provide virtual price and market platform and elements in developing domestic fish marketing policies for future.

# Willingness to pay for conservation of mangroves in Kadalundi-Vallikunnu community reserve

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The Kadalundi estuary (11°7'28"–11°8'1" N and 75°49'36"–75°50'20" E), located at the mouth of the river Kadalundi, drains into the Arabian Sea. The important characteristics of the estuary include eight species of mangrove vegetation with an area of 13.23 ha, mudflats, foraging grounds for avian fauna, sea otters, etc. The mangroves of Kadalundi have the potential to sequester and store 2,409.84 t C. Considering the ecological significance, the Kadalundi estuary with a total area of 153.84 ha has been officially declared as the Kadalundi-Vallikunnu Community Reserve in the year 2007. The estuary has five small islands, in which four have human inhabitation with a total of 182 families live in these islands.

Considering the ecosystem services rendered by the mangrove habitat of Kadalundi-Vallikunnu Community Reserve, it was envisaged to understand the awareness of local people on the importance of mangroves and their concern for its conservation. Contingent valuation (CV) method was applied through conducting a survey in which the local people were directly asked how much they would be willing to pay (WTP) for the conservation of mangroves in Kadalundi wetland. The study

Table 1. Reasons cited by the respondents (in percent) of Community Reserve for their Willingness to Pay (n=36)

| Sl. No. | Particulars | SA | A | N | D | SD |
|---|---|---|---|---|---|---|
| 1. | Because I am more aware about mangroves | 72 | 19 | 6 | - | 3 |
| 2. | It is my moral duty to protect the mangroves | 72 | 28 | - | - | - |
| 3. | Conservation is better for sustainability of the ecosystem | 75 | 25 | - | - | - |
| 4. | Reasonable amount (affordable) | 86 | 14 | - | - | - |
| 5. | Concerned about degradation | 92 | 8 | - | - | - |

*SA-Strongly Agree, A-Agree, N-Neutral, D-Disagree, SD-Strongly Disagree

Table 2. Reasons cited by the respondents (in percent) of Community Reserve for not willing to pay (n=64)

| Sl.No. | Particulars | SA | A | N | D | SD |
|---|---|---|---|---|---|---|
| 1 | I have no spare income but would otherwise contribute | 65.6 | 7.8 | 1.6 | 10.9 | 14.1 |
| 2 | I don't believe the system would bring the changes | 53 | 7.8 | 1.6 | 12.5 | 25 |
| 3 | It is the Government's responsibility | 85.9 | 10.9 | - | 3 | - |
| 4 | I feel that environmental protection of mangroves is unimportant | 21.9 | 1.6 | - | 12.5 | 64 |
| 5 | The user should pay | 46.9 | 28 | 14 | 7.8 | 3 |
| 6 | I fail to understand the question | 6.3 | 1.6 | 53 | 10.9 | 28 |
| 7 | We cannot place a monetary value on biodiversity | 79.7 | 14 | 1.6 | 3 | 1.6 |
| 8 | I would rather have the current situation than pay more | 54.7 | 21.9 | 6 | 3 | 14 |
| 9 | I believe that this improvement will take place without my contribution | 59.4 | 9 | 1.6 | 3 | 26.6 |

*SA-Strongly Agree, A-Agree, N-Neutral, D-Disagree, SD-Strongly Disagree showed that 36% of the respondents were willing to pay for the conservation of mangrove wetland, while 64% of them were unwilling. The obtained WTP value of individual respondents ranged between Rs.120/- (per annum) to Rs.2000/- (one-time payment). Of the 36 respondents, 20 were willing to make one-time payment, while 12 agreed for a monthly contribution and 4 respondents agreed to make yearly contributions. The total WTP of 36 respondents was Rs.33,760/-, with an average WTP of Rs.938/individual/year. All the respondents who were willing to pay either strongly agreed or agreed that they are concerned about degradation and that it is their moral duty to protect the mangroves (Table 1). Of the respondents who were not willing to pay, 65.6% opined that their income is not enough to make any contribution. About 85% of them also felt it is the responsibility of the government to look into conservation activities, while 46.9% of the respondents were of the opinion that the actual users should pay (Table 2). However 20% of the respondents who were not willing to pay agreed to act as volunteers in mangrove conservation programmes. The study indicates that awareness among the local people is imperative to play a crucial role in the sustainable management of mangrove wetlands.

# Fantastic fans and what the fishers know about them!

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Gorgonians (Order: Alcyonacea), commonly known as 'sea fans' and 'sea whips', are globally distributed cnidarians of ecological (animal association, ecosystem formation) and commercial importance (eg. precious corals, bioactive compounds). Owing to its level of exploitation and conservation priority, gorgonians were included in the Scheduled 1 category of the Wildlife Protection Act of India (WLPA). Based on this context, our study makes an effort to tap the knowledge of fishers on gorgonians, by analysing the attitudes and perceptions of these stakeholders towards the conservation of this poorly-known fauna to develop action plans for better education, awareness and conservation efforts. A questionnaire survey was conducted across India's six maritime states and two islands from June/2018 to May/2019. Respondents were selected based on chain referral and snowball technique. The data gathered with semi-structured questionnaires (including open-ended questions) and focus group discussions were compiled and analysed to understand knowledge and perceptions among fishers about gorgonians. Most respondents (85%) identified the presence of gorgonians; in the east coast (94%) and islands (95%) than the west (70%). Only 37% of the respondents stated that gorgonians were legally protected. Most fishers answered the habitat of gorgonian as rocky substrate and over 75% of them landed it as bycatch/discards. Half of the sample population agreed that gorgonians needed protection. Our survey revealed that fishermen though aware of gorgonian presence were largely unaware of their legal status. It also revealed the inefficiency of existing enforcement mechanisms as gorgonians were captured as fishery bycatch/discard. Our results reveal the need for awareness campaigns highlighting the legality and conservation needs for this fauna.

# Estimating the economic benefits of Vembanad estuarine coastal wetland ecosystem restoration programme in Kerala: A contingent valuation approach

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Evaluation of potential welfare benefits is an important pre-requisite for any wetland restoration and preservation programme to be successful. This work used Contingent Valuation Method (CVM) to measure the potential economic value for taking up restoration and preservation of coastal wetland ecosystem services in Vembanad Lake, Kerala. Primary data was used for the analysis by collecting information from selected wetland beneficiaries using probability proportionate technique. The total sample size was 690 respondents staying in the border panchayats of Vembanad estuarine system. The distribution of sample respondents in various categories of activities such as fishers, non-fisher, transportation and recreation were used for the valuation study. Dichotomous choice followed by open-ended valuation questions were used to know their preference and also their willingness-to-pay for various services that can be obtained from wetlands and further the total economic value was estimated. The figure estimated represents the value of Vembanad wetland ecosystem in Kerala and this can be used as an important justification and can be treated as the base value for planning government expenditure on the wetland conservation projects in near future.

# A baseline study on shark fin trade in Dakshina Kannada and Udupi districts, Karnataka, India

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Shark fin trade is one of the most common and hyped illegal trade in the international market. Around 70 million sharks are killed for their fins (Blaber SJM 2009). The fins are considered to be a traditional Chinese delicacy (Clarke S 2007, Roy BJ 2015). India is one of the producers of shark fins.

Present study was conducted in Mangalore and Udupi fish landing sites which are two of the major fish landing centers in the South-West coast of India. The study revealed the trade of dry fins of all shark species from Mangalore to other parts of the country. The common species traded are, Common Thresher shark (*Alopias vulpinus*), Scalloped hammerhead shark (*Sphyrna lewini*), Great hammerhead shark (*Sphyrna mokarran*), Oceanic Whitetip shark (*Carcharhinus longimanus*), Whale sharks (*Rhincodon typus*), Bull shark (*Rhincodon typus*), Tiger shark (*Galeocerdo cuvier*), Bow-mouth guitar fish (*Rhina ancylostoma*), Shovel-nose Guitar fish (*Rhinobatos productus*) and Hard nose shark (*Carcharhinus macloti*) and some ground sharks.

The fins of these shark species are either dried in Mangalore harbor/Malpe harbor or they are traded fresh to other states for curing. Fresh fins are sometimes sold in the local markets to specific buyers by specific traders on demand. The fins are sold according to the size and not according to species. The cost of large fins ranges from 3000-5000 INR per kg, (4-5 fins), medium sized fins cost 3000-4000 INR per Kg (5-7 fins) and small fins cost 2000 INR per kg, (8-10 fins).

Shark fin trade is a network spread across the country. The fins are traded from Mangalore to Bangalore, Chennai, Cochin, Mumbai and Kolkata. From then on they are exported to countries such as Myanmar, China, Singapore and Vietnam. Further studies have to be conducted in order to find the larger trade routes and trade of other marine species.

The intention of this study is to find the shark fin trade in the study area and to identify the trade route. This is a baseline to understand the shark fin trade and assessing the impact it has on the overall shark population.

# Distribution, abundance, and marketing of Billfishes landed at Kanyakumari coast of India

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The billfishes are a group of predatory fish characterized by prominent bills or rostra, and by their large size, including 12 species of true billfish divided into two families and five genera. There are mainly five species of billfishes reported from Indian waters which include *Istiophorus platypterus* (Indo-Pacific Sailfish), *Tetrapturus audax* (Striped marlin), *Makaira mazara* (Blue marlin), *M. Indica* (Black marlin), *Xiphias gladius* (swordfish). The landings of the billfishes along the Indian coast are showing an increasing trend since the 1990s and the estimated landing during 2018-19 was 16382 t (CMFRI annual report 2018). Drift gillnets-cum-longline, handlines, and longlines operated from mechanized and motorized craft contributed maximum to the catches. Billfishes are one of the highest economic migratory fishery resources, landed at Kanyakumari coast throughout the year caught off the Eastern Arabian Sea showing abundance in its distribution along the Laccadive Sea. From the landings, it is known that the distribution of the fishes extends from Off Veraval to Off Maldives. The landings were dominated by *X. gladius* (37%), *I. platypterus* (33%), *M. mazara* (24%), *M. indica* (6%) and rarely *T. audax* during 2017-18. The matured fishes with high Gonadosomatic index were landed mainly from March to May particularly from the Laccadive Sea indicate the presence of spawning stocks. The billfishes thus landed were processed at the harbor itself for easy transportation. It passes through different intermediaries to the consumers through the services of auctioning, head loading, processing, packing and transporting. The wholesaler himself acts as an auctioneer in the scenario. The fishes were auctioned at the rate of Rs.100/- per kg for *I. platypterus*, Rs.120-140/- per kg for *X. gladius* and Rs.160-200/- for Marlins. Since there is no domestic preference, the well-processed fishes packed in plastic and thermocol containers with ice were exported to neighboring states mainly Kerala and the preferred locations are Thalassery, Aluva, Kottayam, Idukki, Changanassery etc and were sold at the rate of Rs.200-350 per kg. The processing plants located at Kanyakumari started exporting the fishes to Ceylon too.

# Gender differences in occupational distributions among fisherfolk of india

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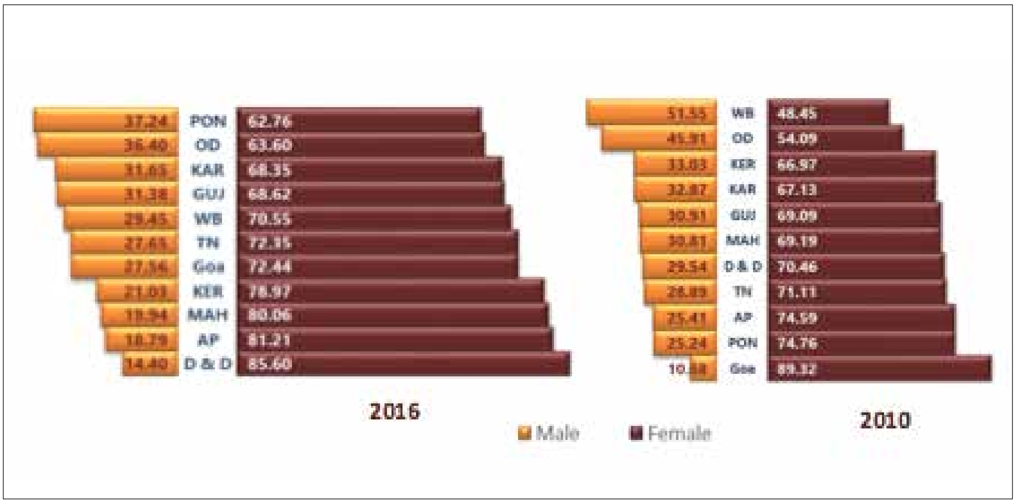
Fishing has been a traditional occupation of a section of people all over the world. The fisheries sector in India, contributes substantially to the nutritional security, provides livelihood opportunities and socio-economic development. Realising the importance of demographic features, socio-economic status and infrastructure of marine fishing villages and marine fish landing centers for developmental plans, a systematic and well organized Marine Fisheries Census was carried out by Central Marine Fisheries Research Institute with the financial support of Government of India in 1980, 2005, 2010 and 2016.

The fisher-folk population in the peninsular India has almost doubled in the past 25 years, increasing from 1.89 million in 1980 to 3.52 million in 2005 and 3.99 million in 2010. According to the latest marine fisheries census conducted in 2016, the fisherfolk population was 3.72 million with 48% females. Tamil Nadu has the country's largest population with 0.79 million, accounting for 21.4%. Kerala was the second largest with a population of 0.56 million. Among the fisherfolk population, more than 1.5 million people rely on marine fisheries for their livelihood with 0.93 million people are engaged in actual fishing operations. In marine fisheries, actual fishing is exclusively a male domain and women are involved in the allied activities such as Marketing of fish, Making/ Repairing Net, Curing/ Processing etc. Among the 0.52 million people engaged in fishing allied activities, women had a high level of involvement forming almost three-fourth of the workforce in this sector. Women's participation and contribution to marketing and processing activities are substantial as they form 90% of the fisherfolks engaged in these activities.

An analysis was carried out to assess the gender differences in fishing allied activities by evaluating the dissimilarity indices and examined the differences and the way in




Gender-wise involvement in fishing allied activities which they have changed over a period of five years. Index of dissimilarity which ranges from 1 to 100 is used to describe the evenness with which two mutually exclusive populations and is calculated as

$$D = \frac{1}{2}\sum_{i=1}^{n}\left|\frac{m_i}{M} - \frac{f_i}{F}\right|$$

Where m$i$ is the male population of the $i^{th}$ occupation, M is the total male population, f$i$ is the female population of the $i^{th}$ occupation and F is the total female population.

As measured by the index the level of occupational difference increased from 39 in 2010 to 44 in 2016, indicating the increased level of involvement of female workers over time. It is also observed that gender concentration of some activities like marketing and processing activities increased over the period. In 2016, among the states, the level of segregation was low in Odisha and Andhra Pradesh. Substantial differences are noticed in women's involvement in allied activities and the degrees of these differences are influenced by several factors such as educational status, religion, ownership of crafts and family size.

# The cuttlebone value chain - a case study from Thoothukudi district of Tamil Nadu

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Frozen cuttlefish is one of the major export commodities contributing 5.2 % of share accounting of 2,356 crores during 2017-18 among the marine fishery products of India. Cuttlebone, which is the calcareous, supporting, protective and buoyancy shield in the dorsal part of the mantle of cuttlefishes has good export value and demand in the export market due to its utilisation of cuttlebone by-products. A study was made to document the cuttlebone value chain from Thoothukudi District of Tamil Nadu through a structured questionnaire (for the exporters) and analysis of the MPEDA cuttlebone export data (2008-09 to 2017-18). The results revealed that for the last few years, Tamil Nadu has emerged as one of the major exporters of cuttlebone, in terms of quantity, where the dried form contributing to a tune of 98% and remaining by the frozen. The cuttlebone value and quantity increased gradually from Rs. 137 lakhs (566 tonnes) during 2008-09 to Rs. 470 lakhs (753 tonnes) during 2012-13. With the increasing demand in the export market, the cuttlebone trade showed a steady increase, reaching Rs. 971 lakhs (982 tonnes) in 2017-18.

In Thoothukudi region, the cuttlebone industries are emerging and about eight cuttlebone exporters besides few retailers are operating and they are contributing nearly 75 % of cuttlebone export from Tamil Nadu. The major importers of the dried cuttlebone from Thoothukudi are Russia, UK, US, China, German, Brazil, Vietnam, Italy and the Czech Republic. Thoothukudi exporters receives raw materials from the processing plants all over India mainly from Thoothukudi, Nagapattinam, Chennai, Kochi, Mangalore, Visakhapatnam and Veraval. The raw material cost depends on the size and season, ranging from Rs. 20 to Rs.100 per kilogram. Simple processing protocols are followed for the export of cuttlebone, which include, grading, sun drying, trimming & shaping, polishing, and packing. The grading and price are based on the size of the cuttlebone. The preferred export sizes are 1-5 inch (Rs.110 /kg), 5-12 inch (Rs.270 /kg) and the broken shells also has export value of Rs.70 /kg. In general, women are mainly engaged in the processing of this product for Rs. 200 to 400 per day as wages. Packaging materials used for cuttlebones are based on buyers demand. Generally Carton box, Polypropylene bags and gunny bags are used for packing. The cuttlebone as powder was used as an artistic carving medium during the 19th and 20th centuries later it has been used in polishing gold, toothpaste, and as antacid for medicinal purposes. In recent years they are used as a calcium-rich dietary supplements for pet birds. The study also revealed that processed cuttlebones are primarily exported as feed for caged birds and the un-processed cuttlebones are exported to the herbal companies for further processing for developing valuable medicinal compounds. A weight loss of at least 5% of the product during shipment leading to economic loss for the exporters due to its highly porous nature.

Theme 7

# Green harvest & zpost- harvest technologies

**mbai-mecos 3**

# New developments in green fishing technologies

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The prerequisites and conditions for commercial fishing will change dramatically in the coming decades with climate change, human population growth, marine pollution, intensive coastal development, overexploitation, biodiversity loss and other global drivers. Major changes in resource distribution and abundance are predicted with a potentially significant loss of marine production. At the same time there will an increasing demand for seafood and ever stricter sustainability challenges. Collateral damage caused by fishing activities will have to be minimized. More sustainable fish capture technologies will have to be developed and adopted while destructive and energy-hungry practices will be displaced. New fishing vessel types, including energy-efficient multipurpose vessels, will emerge. Automatization, digitalization and new energy sources will be widely adopted. New approaches for fish location and attraction will be developed. Capture technologies that are better adapted to rougher sea conditions will emerge. The waste of valuable fisheries resources will be minimized; zero-discards policies will become common. Consumers will demand high-quality and certified products. Live-capture and transportation technologies will become more common. Lower trophic level organisms will be utilized more widely. Many regions will have to learn to catch species that are new to them. Animal welfare issues are becoming increasingly more important. Capture technologies and practices have to meet the wider sustainability and ethical criteria. Fishing industry will have to become a caretaker of marine environment.

# Recent trends in fish processing

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In the global food industry, fishery products have attracted considerable importance as a source of proteins, Poly Unsaturated Fatty Acids (PUFA), vitamins and minerals. Fish is highly perishable commodity and hence suitable processing and packaging techniques helps in maintaining the quality of fish. Driven by the needs of consumers regarding high quality processed foods with minimal changes in nutritional and sensory properties and with the advent of technology, lot of alternative or novel technologies have come into the foray of fish processing and packaging.

High Pressure Processing is an innovative non-thermal technology that has a great potential for extending the shelf-life with minimal or no heat treatment. Pressure Shift Freezing and Pressure Assisted Thawing are getting popular with considerable advantages over conventional processing. Pulsed Light Preservation, involving short time high-peak pulses of broad-spectrum white light, is a non-thermal technology for decontamination of food surfaces and food packages. Similarly, Pulsed Electric Field processing with the application of very short electric pulses at different electric field intensities is used. Ultrasound processing and Ultrasound thawing using sound waves above frequency of 20MHz are used as tools for fish processing. Ohmic heating and Microwave heating are other emerging technologies with large number of applications.

Active packaging involving various active components such as antimicrobials, antioxidants, O2 scavengers, CO2 emitters/absorbers, moisture regulators, flavor releasers have been included in the package system for augmenting the packaging performance. Currently, the use of edible biomaterials, plant derived extracts and nanomaterials are popularized to substitute synthetic additives due to their packaging and waste management notions. Intelligent or Smart packaging is an area which is emerging at a very rapid pace with the development of novel indicators like time-temperature indicators, leakage indicator, freshness indicator, gas indicators; automatic identification devices like barcodes, RFID systems; and sensors like biosensors, gas sensors.

# Characterization of collagen from the skin of commercially important marine fishes from Kerala coast

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Collagen is one of the most abundant biological macromolecules of extracellular matrix where it provides the major structural and mechanical support to tissues. Native collagens from different sources find applications in cosmetics, biomedical and pharmaceutical industries. Skin collagens from different commercially important marine fishes were extracted, analyzed and compared. Acid soluble collagens (ASC) were extracted and characterized using sodium dodecyl sulphate-polyacrylamide gel electrophoresis (SDS-PAGE). Based on SDS-PAGE patterns and subunit composites, all ASC were identified to be type I. Amino acid analysis of these extracted samples was carried out. Denaturation temperature of ASC correlated well with imino acid and hydroxyproline contents. From the study it was found that the skin of marine fish species is a good source of collagen which can be commercially exploited.

# Collagen extraction from airbladders of different marine and freshwater fishes of Mumbai coast

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The marine ecosystems are a hub of species which are rich in many important components and one among it is collagen. Collagen is an extracellular, structural protein and it is said to be associated with aging of skin. Young skin requires good quality collagen and thus it is of much interest to people. The body produces *collagen* naturally and it is in abundance when young, but unfortunately production starts to decline at about *age* 25. Collagen encourages the renewal of cells and minimises facial muscle contraction. The result is firmer, plumper, more youthful looking skin hence it is used in many medical and beauty applications. Basically all collagen supplements and skincare products derive collagen from four main sources: bovine (cows), porcine (pigs), chicken collagen and fish (marine) collagen. Fish collagen, also known as 'marine collagen ', is extracted from either meat, scales or airbladder. Fish Collagen has been shown to have superior "bioavailability", as compared with other animal source which means fish collagen enters the bloodstream more quickly than other types of collagen, making it the best collagen to replenish your body's collagen. Fish collagen contains Type I collagen, which is 85% of our skin collagen and the building blocks of our skin's structure. The majority of other animal collagen derived from bovine, chicken, or pork is Type II collagen, which can be beneficial for joints, but doesn't help skin.

The fish airbladder is reported to contain a very good source of collagen around 70-90 % and the composition and yield varies with species. But this airbladder which is a good source of collagen is treated as waste and largely remained unutilised and discarded. It can be sustainably utlilised to extract its prime most component collagen for its judicious use. A lot of work has been done on collagen extraction from airbladder but only a few works are reported with properties of collagen when extracted from a mixture of airbladders of different species extracted together against the property of collagen extracted from individual species.

# Method for producing flavoured live oysters and results from taste panel

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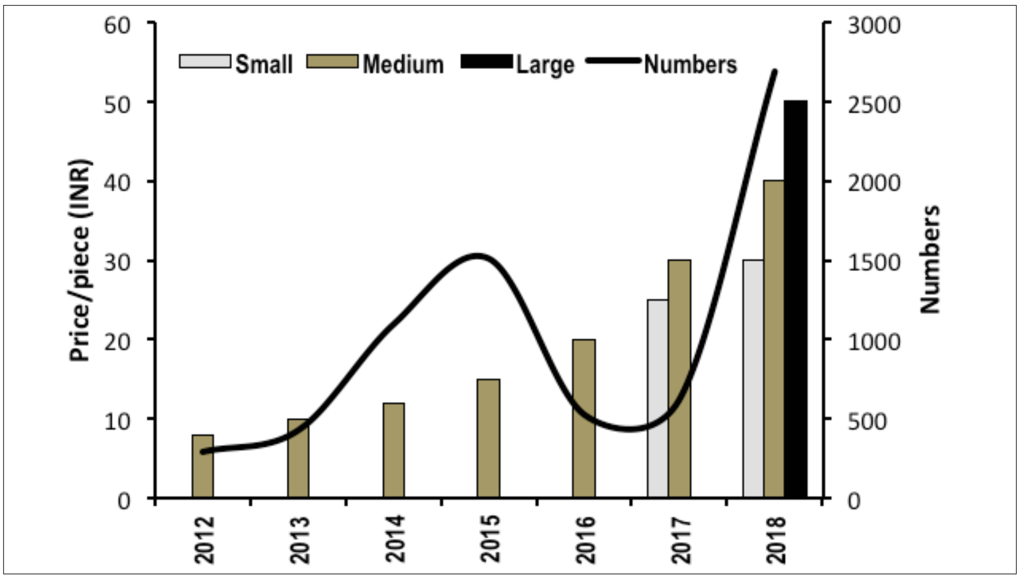
Value-added-products (VAPs) from the edible oysters *Crassostrea madrasensis* experienced tremendous growth and wide consumer acceptance in Ernakulam District. Oysters are considered the healthiest when eaten live. The live oyster value chain was developed in the city of Kochi on small scale and has great scope to expand to other metro cities. In this study, an attempt was made to develop live flavoured oysters having cardamom, orange and ginger flavour. A total of 5 trials were carried out. In each trial, oysters were subjected to 18 h depuration and depurated oysters were treated with different quantity and duration of flavoured concentrate in 5 l water. The following were the treatments: Ist experiment-1 ml flavoured concentrate (control / ginger / cardamom, 1h & 2h); 2nd experiment-1 ml flavoured concentrate (control / orange / cardamom, 3h); 3rd experiment-1.5 ml flavoured concentrate (control/orange/ cardamom, 3h); 4th experiment-1.5 ml flavoured concentrate (control / orange / cardamom, 4h); 5th experiment-2 ml flavoured concentrate (control/orange/cardamom, 3h).

A preliminary study was carried out among the 10 panel members to know the preferences among the type of flavoured oyster based on 10 point grade. Results suggest distinct differences in behavior among the panelists. Most of the panelists' sensed orange flavor as lemon in 2nd experiment while ginger as salty in 1st. However, cardamom flavor was the most preferred among the flavoured oyster in almost all the trials. Further, detail experiments have to be carried out with more flavours in order to develop the most preferred flavoured oysters. The outcome of findings will be valuable for oyster growers and processors for getting more income per unit.




Live oyster trade in Kochi

# Comparative analysis of salted Indian mackerel (*Rastrelliger kanagurta*) dried by different drying methods

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A comparative study was done to evaluate the effect of different drying techniques on the Indian mackerel (*Rastrelliger kanagurta*). Fresh mackerel of length around 17-21 cm were used. Further eviscerated, washed and salted with dry salt in 3:1 ratio for 2 days. Solar dryer and mechanical dryer were used to prepare salted dried mackerel in the laboratory. However, salted sun dried mackerel procured from Malvan fish market of Sindhudurga District of Maharashtra coast was used as control. The proximate content, sensory attributes, bio-chemical and micro-biological characteristics were analysed. From this study it is revealed that the overall quality of salted fish dried in mechanical dryer were found better than the fishes dried under solar dryer and direct sun. In the present study, it is found that for better quality of salted Indian mackerel, the fishes should be dried in the mechanical dryer at 500$^{\circ}$C for 16 hours as against in the solar tunnel dryer for 3 days.

# Development of jellyfish excluder device for trawls:Performance of Grid-1

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Jellyfish population in the coastal waters has increased enormously in the last few years and rising seawater temperature, changes in water quality, current patterns and trophic level changes are some of the reasons ascribed to this. Jelly blooms affect most of the fisheries in the marine and estuarine waters and the impact is severe for fishing gears like trawls and bag nets. Several trawls were damaged and in extreme cases mast and derrick system were broken, while lifting the codend, due to large amount of jellyfish in the codend. The net gets filled with jellyfish with concurrent increase in the drag leading to high fuel consumption. Majority of the trawlers stop operations during the peak season of jellyfishes. An attempt was made to develop a Jellyfish Excluder Device (JED) to reduce the jellyfish catch in trawls and allow for normal operations. An oval stainless-steel grid (1mx 0.8 m) size with 16 vertical bars with 50 mm distance between was fixed in the trawl at an angle of 45º in the hind belly before the codend. The opening immediately before the grid, had a flap cover to prevent inadvertent escape of fishes.

A total of 19 hauls of 30 minutes duration each, were carried out using a 32m shrimp trawl fitted with JED onboard ICAR-CIFT Research vessel RV. Matsyakumari-II ($L_{OA}$ 17.7m, 325hp) in the depth range of 8 to 15 m off Cochin. Speed of trawling ranged from 2.5-3.5kn. Total catch (retained and excluded) was 2067.3kg in which 1866 kg (90.26%) was jellyfish. About 72.0% jellyfish entered in the trawl were excluded through the device and only 28.0% was retained in the trawl. Retained jelly fishes are either smaller in size or are without a particular shape, which were able to pass through the grid. Total fish catch was 201.8kg, in which 42.60% was retained in the codend and 57.38% was excluded through the device along with jellyfish. A total of 43 finfish species were recorded in catches of which 27 were completely juveniles (below MLS). Preliminary analysis reveal that the results are encouraging and more trials are required with grids with different bar spacings to optimize the jellyfish excluder device.

# Trends in the fisheries for tuna resources along Lakshadweep islands

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Lakshadweep islands which are spread along the southeastern Arabian Sea has a fishery potential of one lakh tonnes and is widely known for its pole and line fishery for capture of Skipjack Tuna. In addition to the traditional pole and line fishing, different types of gears are operated from the Islands, which include troll lines, handlines, encircling gillnets etc. There has also been an increase in the capacity and effort for the capture of fishery resources in the recent years, with fishing vessels, from the mainland acting as carrier vessels. These vessels exclusively collect fish from the vessels of Lakshadweep, with permit from the fisheries Department since 2016. Traditionally yellowfin fisheries were not a target since 2016, but with assured market after the introduction of the scheme for collection vessels, the catches of yellowfin catch, and prices have gone drastically higher. The profile of the fish catches and the effort data from 2014 pertaining to four Islands, viz., Agathi, Andhroth, Kavaratti and Minicoy, were analyzed to understand the changes in the fishing power and related changes in the regions. It is observed that there has been a significant increase in the yellowfin catches in the recent years, though the traditional catches of skipjack are maintained. The catch profile and the changes in the fishery in the region and the need for optimum effort for sustainability, is highlighted in the paper.

# Demonstration and popularization of square mesh codends along Sindhudurg district, Maharashtra - a success story

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Trawling is implicated with generation of large quantities of bycatch and shrimp trawling along the tropical waters contribute the most bycatch and discards in the world fisheries. The discards by trawlers operating along the Indian coast is estimated at 1.2 million tonnes in 2010 and more recent reports show that low value catches are increasing in the Indian trawl fisheries. A large number of gear-based technical measures have been developed to reduce the incidence of bycatch in trawling in Indian waters. However the adoption of these, are very poor among the fishers and one of the main reasons for the lack of adoption, is due to the fear of catch loss resulting in reduced revenue, which is often a wrong assumption. The short-term loss happening cannot be considered as loss, rather an investment, if the escapees are allowed to grow reach commercial sizes. Though experimental evidence exists, the demonstration and popularization of the bycatch reduction devices in trawling sector in India has been poor. Baring a study, carried out along Gujarat waters, using square mesh codends, there are no models which have shown the utility of using bycatch reduction devices in the actual commercial conditions. Square mesh codends are found to be better liked by the fishers, mostly due to its conceptual simplicity and ease of rigging to the existing gears.

The coast of Sindhudurg, is an important trawl landing centre along the west coast of India with a total production of about 24000 tonnes. The District has a total of about 317 trawlers in the length class of 12 to 15 m $L_0A$. Though there are no reports from the Sindhudurg coast, the bycatch generated by trawlers along Maharashtra coast are significant forming 8% to 15% of the total catch and there had been a general decline in the fishing for some years. It was in this backdrop, that UNDP had funded a project, which ICAR-CIFT has taken up, to demonstrate and popularize the use of square mesh codends along the Sindhudurg District. The problem was addressed in a three-prong strategy, which included extensive awareness programs, hands-on training on the fabrication of codends, mass coverage in media and on-board trials using commercial vessels of the region.

A total of 14 awareness programs were conducted in which 347 fishers were trained and 6 netmakers and 2 vessel owners were trained specially for the construction of square mesh codends from diamond meshes. For the square mesh trials in commercial trawlers, the boats from local owners were selected and a cover was attached to the square mesh codend to guage the escapement from the square meshes. A total of 140 hauls were conducted with each codend for a period of one year in four trawlers from three talukas of the District.

The commercial trials showed that the escapement CPUE, as measured by weighing the fishes in the codend cover was only 2.45 kg/h, which consisted predominantly of juveniles of commercially important species. The value at the rates prevalent then was only Rs. 180/- for three hauls. According to the fishers, there was a savings in the fuel also, due to the low drag offered by the square mesh codends.

This multi-pronged strategy was well adopted by the fishers in the region and UNDP in collaboration with Govt. of Maharashtra had developed a plan to distribute trawl codends to all the trawlers operating in the Sindhudurg District as replacement for the existing codends. As an outcome of the results of this study, the Govt. of Maharasthra in 2017 modified its Marine Fisheries Regulation Act by making use of 40 mm square mesh codends mandatory for all the trawlers operating in Maharashtra. The different steps involved and the detail of the catch and bycatch and adoption strategy is discussed in the paper.

# Automatic fishing boat detection and counting from satellite images

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Use of artificial intelligence in natural resource management is picking its pace lately. Marine fisheries is also not alien to its adoption. The management of marine capture fisheries in India faces difficulty due to the lack of monitoring, control and surveillance mechanism. Conservation planners face growing pressures to combat illegal fishing widely happening along their EEZ. Many a time, due to the large coastline and the difficulties in surveillance, the enforcing agencies are unable to monitor the actual number of boats even though there might be recorded data on the number of licenses released. This calls for the need for a robust and generalized system that can automatically count and detect boats from satellite images with the help of open-source data and tools. Even though the object counting from the aerial and satellite imagery is a common problem addressed by image processing, when the object counting coming into the picture, instance segmentation is the better option that solves the issue of object detection and segmentation. Here we are attempting to test the applicability of You Only Look Once (YOLO) v3 and Mask (Region Convolutional Neural Network) R-CNN algorithms for its utilisation in the counting of fishing boats at Veraval coast of Gujarat. The Google Earth images have been collected during the month of May 2015 just before the trawl ban period so that maximum boats are available at the harbour itself. The results indicate that the algorithms are efficient in counting the fishing boat estimates from the satellite image. The applicability of these algorithms can be further utilised in monitoring and surveillance of the fishing boats countrywide and hence the illegal boats can be controlled. This technological advancement will help the decision-makers to efficiently accelerate the enforcing mechanisms and achieve the objectives of sustainable fisheries.

# Studies on shelf life of cook-chill storage of green mussel in curry

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The green mussel (*Perna viridis*) and the brown mussel (*Perna indica*) occurs on the Konkan coast and are commercially important marine mussel from the Indian coast. The mussels are generally utilized in fresh form or by preparing canned products in brine, oil and masala. In recent years, several attempts have been made on cook-chill products in ready to eat form. In the present study, an attempt has been made to evaluate the shelf life of pasteurized green mussel in curry, packed in pouches and stored under chilled temperature (0°C to 2°C). The biochemical analysis such as TTA, Peroxide Value and FFA, pH, TMA-N and TVB-N values were studied. In this study it is revealed that the pasteurized green mussel in curry can be stored upto 16 days at 0°C to 2°C.

# Combined effect of lemon peel extract, green tea leaf extract and chitosan as edible coating on the quality and shelf life of Indian mackerel stored under ice

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The conditions after the harvest of fish affects post mortem stages and accelerate deterioration due to protein degradation, lipid oxidation and decomposition caused by microbial or endogenous enzymes, resulting in a short shelf-life. Lipid oxidation promotes the development of compounds which have detrimental effects on the standard characteristic and dietary value of seafood products. Considering the ill effects of synthetic preservatives and anti-oxidants, there is a need to replace the chemical ingredients in use with natural alternatives.

Fresh Indian mackerel (*Rastrelliger kanagurta*) fish samples were divided into five lots viz., (i) Control, (ii) coated with LPE 1%, (iii) coated with GTE 1%, (iv) coated with CH+LPE+GTE 1% and (v) coated with CH+LPE+GTE 2% stored under ice for 15 days. Determination of phytochemical contents of LPE and GTE extracts and their anti oxidant activities were determined along with proximate composition, physical analysis and chemical analysis (total volatile base nitrogen and trimethyl amine nitrogen, peroxide value, free fatty acid and thiobarbituric acid reactive substances) were also carried out every 3 days interval during the storage under ice.

The extraction yield % of LPE was lower than GTE. Total flavonoid content and DPPH radical scavenging activity were higher in LPE than GTE. The proximate analysis result indicated that the moisture, protein, fat and ash contents significantly varied during storage ($p < 0.05$). Comparatively higher sensory scores were obtained for coated samples at the end of storage ($p < 0.05$). The drip loss values increased progressively in all samples. Textural profile analysis indicated that hardness, springiness, cohesiveness and chewiness values of treated samples showed a decreasing trend, except in the case of samples treated with CH+LPE+GTE 1% and CH+LPE+GTE 2%. The level of TMA-N in fatty fish after the 15th day of storage was 10.02±0.02, 9.92±0.10, 8.10±0.10, 7.33±0.06 and 7.17±0.12 in Control, LPE 1%, GTE1%, CH+LPE+GTE1% and CH+LPE+GTE 2% respectively. TVBN value of control sample recorded the maximum acceptable limit, at the end of storage. Gradual increase in PV&FFA value was recorded in control, LPE1%, GTE1%, CH+LPE+GTE1% and CH+LPE+GTE 2% respectively. TBARS values also changed significantly during storage ($p < 0.05$). Combination of edible coating (CH+LPE+GTE 1%) was found effective than other treatments and can be recommended as a natural anti-oxidative and preservative agent for fatty fishes during iced storage and transportation.

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