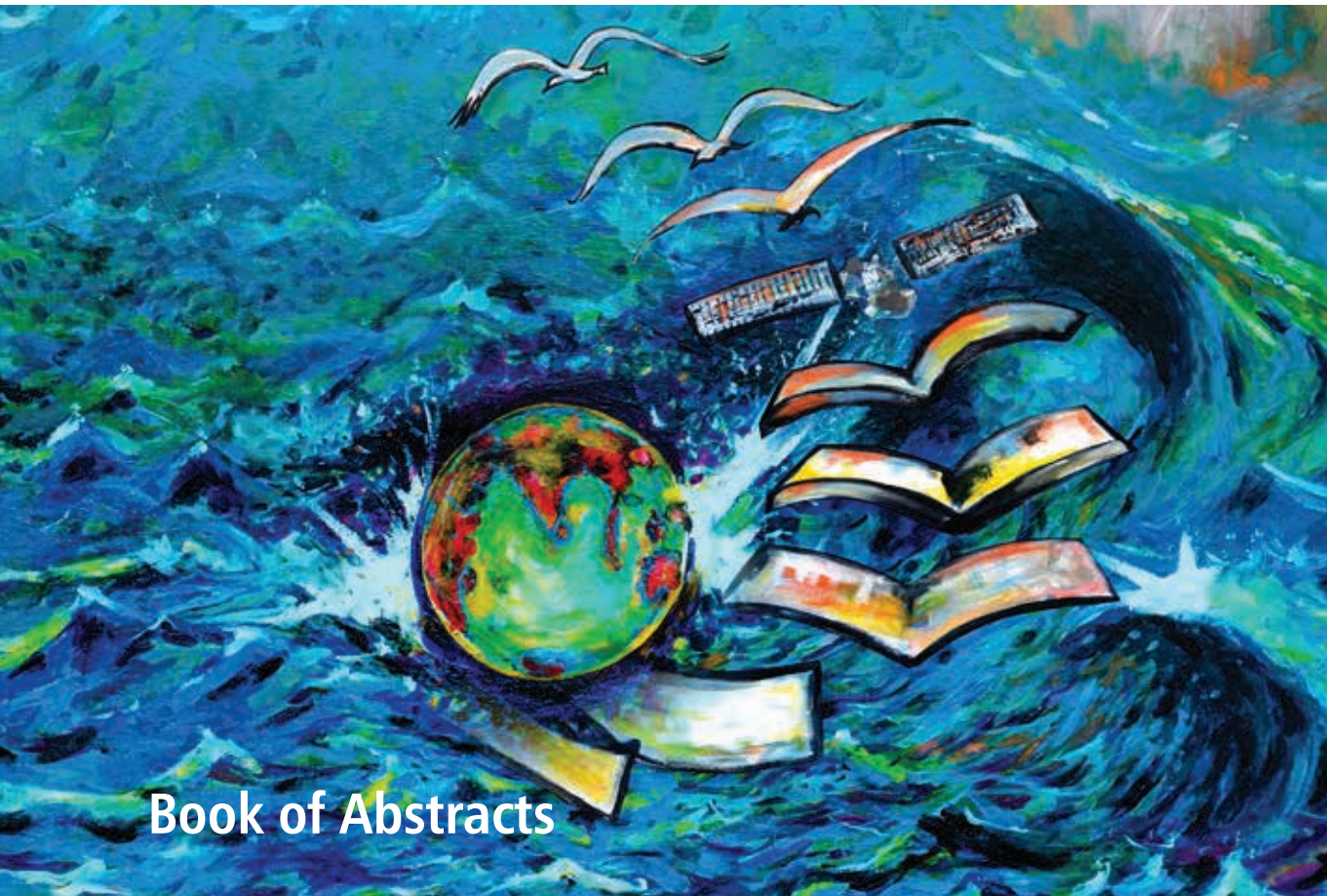# MECOS 2

Marine Ecosystems
Challenges & Opportunities
International Symposium | 2-5 December 2014, Kochi, India

MBAI *Marine Biological Association of India*

Book of Abstracts

MECOS 2

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Organised by

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Marine Ecosystems
Challenges and Opportunities (MECOS 2)

Editors
Dr. P.U. Zacharia, CMFRI, Kochi
Dr. P. Kaladharan, CMFRI, Kochi
Dr. Molly Varghese, CMFRI, Kochi
Shri. N. K. Sanil, CMFRI, Kochi
Dr. Rekha J. Nair, CMFRI, Kochi
Dr. Aswathy. N, CMFRI, Kochi

Foreward

Marine ecosystems cover approximately 71% of earth's surface, hold 97% of the planet's water and account for 32% of worlds primary production. Coastal and marine ecosystems provide services, such as food, fuel, timber, mineral resources, and pharmaceuticals, and play key regulating and supporting roles (eg, climate regulation, nutrient cycling, and storm protection). Marine ecosystems play host to a variety of species ranging from plankton which form the foundation of the marine food web to the large predators which form the apex of the food web. Hence, they have an important role to play in the overall health of both marine and terrestrial environments. These ecosystems which are essential for maintaining life on our planet therefore provide key services both globally and locally. Nevertheless, in spite of their widely recognised value, marine ecosystems of the world face multiple challenges, some natural, but many resulting from human interventions. Many ecosystem services provided by coastal and marine ecosystems are on the decline (Millennium Ecosystem Assessment, 2005). Climate change is a reality now accepted by most of the scientists and warming seas and rising sea levels is considered as a consequence of this. Pollution of the seas including debris, ghost nets, sea usages like mining, indiscriminate and unregulated fishing has only added fuel to the increasing deterioration.

To address these concerns and utilise the discussions to convert the challenges faced into opportunities, the Marine Biological Association of India, in 2009, organised the International Symposium MECOS-09. It was aimed to bring together scientists working on marine processes, fishing, climate change, pollution, loss of habitat and marine biodiversity and to discuss technological and organizational challenges for global ocean sustainability. The MECOS-09 was a resounding success with over 755 authors from 60 affiliations taking part. Looking ahead, since the present situation is graver than in 2009, it was decided to host the second MECOS in 2014 as MECOS 2 to address and assess the current status of the marine ecosystems of the Asia Pacific region.

The MBAI was established in 1958 with the primary objective of promotion of scientific research in the field of marine biology and allied science. The MBAI has on its roll 697 life members and 35 institutional members. The association has been fulfilling this objective by creating active interest among the members by periodically organising symposia, seminars on specific areas of topical interest. MBAI has conducted 9 international symposia and several seminars so far. MECOS-2 has attracted abstracts from scientists, researchers and teachers from India and abroad. A total of 255 abstracts were received under the six tracks viz., Marine Fisheries and Management (56 abstracts), Aquaculture Production Systems (41 abstracts), Marine Biodiversity, Climate Change and Ecosystem Assessment (73 abstracts), Responsible Harvest and Post-harvest (18 abstracts), Marine Biotechnology (51 abstracts) and Livelihood and Economics (16 abstracts). The book of Abstracts contains all the 255 abstracts and four invited keynote/lead talk articles. The major contributors are Central Marine Fisheries Research Institute, Cochin University of Science and Technology, Fisheries Universities, M S University of Baroda, Central Institute of Fisheries Technology and Central Island Agricultural Research Institute.

A quick perusal of the abstracts indicate that the main prioritised areas are

marine biodiversity, marine fisheries management, climate change and ecosystem assessment. Notable contributions are prediction models for forecasting small pelagic resources, bio-fuel production potential from macroalgae, mitigation measures against ocean acidification, fishermen awareness about climate change, new insights about distribution shift of oil sardine, coral diversity of Laccadives, ICT strategy to reduce climate change, application of geospatial techniques to predict sea level rise, diversity and distribution of marine living resources from Andaman and Nicobar islands and Laccadive archipelago, emission of CHGS from aquaculture systems. Under marine biotechnology, evaluation of genetic diversity and fish stocks using molecular characterisation, identification of immune gene associated with WSS, degradation of industrial waste using marine isolate, development of fish vaccine and use of plant extract against Vibrio are significant. Under responsible harvest and post harvest, estimation of fish harvest using chlorophyll based method, production of high value added products from fish waste, self governance by mussel fishermen from Malabar region are mentionable. Under marine fisheries management, aging tropical fish/cephalopods using hard parts, biological studies on major resources, impact of trawl ban on stock revival, destructive fishing by some gears and new database for marine fishery informatics are noteworthy.

Open sea cage culture with fishermen participation, role of microfinance on indebtedness in marine fisheries, traditional fish harvesting methods of Nicobari tribes and gender integrated value chain analysis are the major highlights of the session on livelihood and economics. New preservations techniques for shellfish and finfish, technical efficiency of small scale fishing units, present status of the sea cucumber in GOMBR are the interesting papers in the harvest and post harvest session.

A highlight of the Symposium is that we have received abstracts on less known groups, migratory patterns of Olive Ridley turtle, aggregation of sea snakes, porpoises, snapping shrimp to name a few.

We thank all those who have contributed abstracts to the MECOS 2 Symposium and hope that fruitful deliberations leading to conservation and sustainable utilisation of the marine ecosystem will emerge.

27-11-2014   Editors

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Track 2

FAO Guidelines on Small-scale Fisheries and its Implementation in the Indian Context: Issues and Challenges

Venugopalan, N.
International Collective in Support of Fishworkers (ICSF), 27 College Road, Chennai- 600 006, Tamil Nadu, India. Email: icsf@icsf.net

The Voluntary Guidelines for Securing Sustainable Small-scale Fisheries in the context of Food Security and Poverty Eradication (or, SSF Guidelines, in short) were adopted by the Food and Agriculture Organization of the United Nations (FAO) in June this year.

The SSF Guidelines, among other things, aim at enhancing the contribution of small-scale fisheries to food security and nutrition; to the equitable development of small-scale fishing communities; to achieving sustainable utilization and conservation of fisheries resources; and to providing guidance for ecosystem-friendly and participatory policies, strategies and legal frameworks for responsible and sustainable small-scale fisheries by employing a human-rights-based approach to fisheries.

Implementing the FAO SSF Guidelines in India could be attempted at several levels:

First, by examining how SSF could enhance its contribution to food security and nutrition. This would presuppose that enough opportunities are afforded to both marine and inland small-scale fisheries in India to supply edible fish at affordable prices to the poor and marginalized along the coast as well as in the hinterland. Providing opportunities to fish would imply that small-scale fishers' access to fishing grounds and resources is protected and is not threatened.

Second, by ensuring equitable development of small-scale fishing communities, which is to be secured by protecting access of small-scale communities to education, health, housing sanitation and social welfare policies and programmes, especially by employing the Directive Principles and other human rights provisions of the Indian Constitution, and also by the active participation of relevant ministries and departments.

Third, by improving and implementing legal and policy provisions to reduce conflicts between active and passive gear groups, to conserve and manage fisheries resources, through the adoption of effective conservation and management measures for sustainable and responsible fisheries and the protection of the marine ecosystem, in particular. There are different sets of policy and legal issues involving marine and inland capture fisheries.

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Based on the recommendations of the SSF Fisheries Workshop in Kolkata in 2012 in preparation for the Guidelines negotiations in Rome during 2013-14, the presentation will also look at a possible definition of small-scale fishing in the context of India; or alternatively, what types of marine fishing should receive priority attention or treatment under the rubric of small-scale fisheries in India, especially in the marine context.

The presentation would argue how small-scale fisheries are the best suited to remove poverty and provide food security to rural coastal and riparian populations in India, and how implementing the SSF Guidelines, particularly employing a human-rights-based approach, would provide a unique opportunity to deal with life and livelihood issues of small-scale fishing communities and sustainable fisheries within a coherent and inclusive framework.

Challenges in developing a mariculture production system

Gopakumar, G
Central Marine Fisheries Research Institute, Mandapam Regional centre, Mandapam Camp 623 520, Tamil Nadu, India Email: drggopakumar@gmail.com

Fish is a vital source of protein and essential nutrients for the comparatively poor section of our society. The demand for fish is increasing year after year and the undernourished sector of our society is dependent heavily on fish for eliminating their hunger, promoting health and reducing poverty. Recent estimates quantify the per capita fish consumption in India around 8-10 kg per year and is likely to grow to 16.7 kg by 2015. In this regard, the marine fish production of the country plays a vital role. The marine fish production iscontributed almost entirely from capture fisheries. In recent years, the capture fisheries scenario in India is characterized by increased and excessive fishing effort, overexploitation of certain resources from the inshore grounds and increased conflicts among the different stakeholders in the sector. Due to the larger dependency on inshore fisheries over the years, the production from near shore waters has reached a plateau and hence further increase in fishing effort may not be a sustainable option to augment the marine fish catch. The marine fish landings in India in 2013 declined to 3.78 million tonne as against 3.94 million t in 2012. In this context, mariculture is a potential sector which can enhance the seafood production for meeting the additional demand for fish in the near future.

Globally, mariculture produces many high value finfish, crustaceans, and molluscs like oysters, mussels, clams, cockles and scallops. In 2012 mariculture has contributed around 24.7 million tonnes of foodfish globally which formed about 35.7% of the aquaculture production. Molluscs dominated the global mariculture production (60.3%) followed by finfish (22.5%), crustaceans (15.9%) and others (1.3%). In addition about 23.8 million tonnes of macroalgae and seaweeds were also produced by mariculture. In India the potential of mariculture production largely remains untapped. The mariculture activities are confined only to coastal brackish water aquaculture, chiefly shrimp farming. The other coastal aquaculture activities are green mussel farming which is confined to Malabar coast in Kerala with an annual production around 15,000 tonnes and seaweed farming along Ramanathapuram, Puthukottai, Tanjore,Tuticorin and Kanyakumari districts of Tamil Nadu producing about 17,000 tonnes wet weight annually.

In India, brackishwater aquaculture is a significant contributor to seafood production, constituting mainly the shrimps like *Penaeus monodon* and *Litopenaeus vannamei*. However, it was realised that the vast coastal waters and saline water bodies which are suitable for mariculture where varied resources such as oysters, mussels, crabs, lobsters, sea bass, groupers, cobia, pompano, and seaweeds that have the potential to capture new markets with a wide range of seafood products could be farmed had led to the consideration of them as

candidate groups. Hatchery and rearing techniques have also been standardised for many of these groups by the Central Marine Fisheries Research Institute (CMFRI). Marine finfish farming is gaining attention and in the recent past a lot of research attention was focused on the seed production of high value marine finfish and currently commercial level seed production techniques of three species of marine finfish - sea bass (*Lates calcarifer*), Cobia (*Rachycentron canadum*) and silver pompano (*Trachinotus blochii*) which have very high potential for mariculture have been developed. Seed availability is the major constraint for the initiation of commercial level farming of marine finfishes and shellfishes. Hence there is an urgent need to establish marine finfish hatcheries by fisheries development agencies /private sector to ensure the seed availability. In addition, it is required to intensify research programmes for the development of seed production techniques for at least one dozen species of high value marine fishes. The commercial level farming of lucrative shellfish species like the sand lobster, *Thenus unimaculatus* and the blue swimmer crab *Portunus pelagicus* can also be practiced if hatchery produced seeds are available. Eventhough experimental success in the seed production of both the species was obtained the techniques still remain to be standardized.

The sea cage culture has been expanding in recent years on a global basis and it is viewed by many stakeholders in the industry as the aquaculture system of the millennium. Cage culture has made possible the large-scale production of commercial finfish in many parts of the world and can be considered as the most efficient and economical way of rising fish. In India, lot of research attention was given in the recent past to develop sea cage farming and successful demonstrations were conducted at many areas of Indian coast. Cobia, Sea bass and spiny lobsters were the major groups employed for farming. These demonstrations have created an awareness regarding the prospects of sea cage farming in India. Many entrepreneurs, fishermen and farmers are coming forward to take up this venture. To promote sea cage farming in the country, identification of suitable sites with proper depth, water quality and water current are required. Survey and identification of sites suitable for cage farming deserves urgent attention. Further, policy for leasing the suitable sites, bank finance, and governmental support through subsidy assistance are the needs of the hour.

Bivalve farming is being practised at a modest level in the country. Technologies for culture of bivalves viz. raft method (in bays, inshore waters), rack method (in brackishwater, estuaries) or long line method (open sea) are available. These methods are commonly adopted for mussel farming (*Perna indica* and *P. viridis*). A complete package of technology for edible oyster (*Crassostrea madrasensis*) culture has been developed which is presently being widely adopted by small scale farmers in shallow estuaries, bays and backwaters. Spat collection is done mainly from the wild for both oyster and mussel. In the long run it may not be possible to meet the seed demand from wild collection alone. Hence the seed production techniques already developed for edible oyster, pearl oyster and green mussel need to be scaled up to commercial level production as per the requirement of the sector. CMFRI had successfully developed and standardised a simple technique for value added marine pearls, called mabe pearls. A mabe pearl is a dome shaped or image pearl produced by placing a miniature image against the side of the oyster shell interior. The result is an exquisite pearly nacre coated image. The main advantage is the very short gestation period (2 months) and the superior quality of the nacre of Indian pearl oyster *Pinctada fucata*. The bivalve farming which is

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already being practiced at a few locations can be further expanded. The carrying capacity assessment, low value availability of hatchery produced seed and the feasibility of open sea farming of bivalves require attention by the R&D sector.

On a global basis a lucrative marine ornamental fish trade has emerged in recent years. A long-term sustainable trade of marine ornamental fishes could be developed only through hatchery produced fish. CMFRI has pioneered in the development of techniques for breeding, seed production and culture of more than a dozen species of marine ornamental fishes which are in heavy demand in the national and international trade. They include *Amphiprion percula, A.ocellaris, A. perideraion, A. ephippium, Dascyllus aruanus, Pomacentrus caeruleus* and *Chrysiptera cyanea*. Hatchery production and culture of marine tropical ornamental fish is very lucrative due to the high price per unit of ornamental fish.

Sea weed farming has the potential to develop in large productive coastal belts and techniques had already been developed and demonstrated. Recently the culture of the carageenan yielding sea weed *Kappaphycus alvarezii* has become very popular due to its fast growth and less susceptibility to grazing by fishes. A concerted effort by the developmental agencies for popularization of sea weed farming is warranted.

On a global basis, the mariculture practices are dominated by intensive monocultures which have led to sustainability problems, environmental degradation and consequent disease problems. In this context, the idea of bio-mitigation of the environment along with increased biomass production by integrating commercially important species of different trophic levels (eg. seaweed, bivalve and finfish) is emerging as an innovationin aquaculture- Integrated Multi Trophic Aquaculture (IMTA). The development of IMTA in marine and coastal environments has not been demonstrated as a viable enterprise in India and hence there is an urgent need to impart front line demonstration on this potential sector of mariculture to different stake holders.

Mariculture has to emerge as a significant sector of seafood production to meet the additional requirement of fish in the near future. It is required to plan for an annual production target of 1 million tonnes of fish from mariculture in the next 10-15 years. The challenges with regard to seed availability and farming aspects have to be addressed by keeping this target in mind. The development of commercial level seed production technologies for a few species of high market value finfish and shellfish, establishment of finfish hatcheries by fisheries development agencies, identification of appropriate cage/coastal farming sites, development of economically viable farming protocols, formulation of suitable grow-out feeds, health management protocols, development of mariculture policies, evolving suitable extension methods and appropriate marketing strategies can go a long way to promote mariculture as a substantial contributor of sea food production of India.

Challenges in tackling climate change impacts on marine ecosystems

Vivekanandan, E
Former Principal Scientist, Central Marine Fisheries Research Institute, Kochi 682 018, Kerala, India.
Email: evivekanandan@hotmail.com

Marine ecosystems are areas of high biodiversity, providing important ecosystem goods and services to industries and people. These ecosystems are at risk from climate change, and impacts are already being observed in many species and ecological communities (Vivekanandan, 2011). With increasing awareness on the impact of climate change, we have now recognized that a number of key questions need to be addressed. For reducing the vulnerability of climate change on marine ecosystems, we should know (i) how climate change has altered the distribution and abundance of marine species and communities; (ii) which are the candidate indicator species for understanding the impacts; (iii) what are the sensitive areas and hotspots; (iv) how the productivity is altered; (v) among different stressors, what is the proportion of climatic stressors that increase the vulnerability; (vi) what information is required to develop adaptation options; and (vii) how to develop adaptation decisions to assist policy makers. As answers to the above questions are sparse, and little modeling is available for marine ecosystems, there remains a critical gap in formulating a strategic national assessment of climate change impacts so that appropriate policies and management strategies can be developed.

For effectively reducing climate change impacts, it is important to address other human-related threats such as overfishing, pollution and habitat degradation (Brander, 2008). There is a need for integrated management actions with the goal of increasing adaptive capacity of ecosystems by considering climate change as a component of a suite of several anthropogenic influences. The elements underpinning adaptation options are to (i) increase resilience of coastal communities, (ii) improve ecosystem management system, (iii) strengthen institutional mechanism, and (iv) engage in long-term adaptation planning. To achieve this, a framework of adaptation strategies (Fig. 1) should be developed by (i) assessing vulnerability to climate change, (ii) formulating and prioritizing adaptation options, (iii) implementing management options, (iv) monitoring and evaluating the effectiveness, and (v) reviewing the strategy as and when required. Management need to be coordinated and integrated across sectors to reduce current stressors such as overexploitation of marine resources, pollution and deteriorating habitat and water quality, etc.

For this, a new management paradigm is required. Management marine ecosystems under future climate change will require an ecosystem-based approach to conservation, explicitly considering the cumulative effects of multiple stressors (Johnson and Holbrook, 2014). As Ecosystem Approach to Fisheries Management (EAFM) provides a good framework for understanding and adapting to climate change impacts, there is potential for developing operational guidelines on

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incorporating climate change into EAFM plan. Ecosystem approach for climate change adaptation is relatively a young concept. It has been defined as the use of biodiversity and ecosystem services as part of an overall adaptation strategy to help people to adapt to the adverse effects of climate change. For this, a number of scaling factors such as ecological, temporal, socio-economic, legal and jurisdictional should be considered.

Fig. 1. A framework for tackling climate change impacts on marine ecosystems

Climate change impacts on marine ecosystems are expected to be widespread and manifest along the vast coastlines, increasing the challenge for conservation management. For developing countries like India, where even the conventional conservation measures such as marine protected areas are not firmly rooted, moving towards implementing adaptations with robust solutions is a great challenge. It is imperative that the country takes up the challenge as a priority before the climate change impacts assume irreversible proportions.

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Challenges in application of marine biotechnology in tackling issues in marine fisheries and aquaculture

Bright Singh, I. S.

Coordinator, National Centre for Aquatic Animal Health, Cochin University of Science and Technology, Lake Side Campus, Kochi 682 016, Kerala, India. E mail: isbsingh@gmail.com

Introduction

The components of marine biotechnology which have greater and direct implications in marine fisheries and aquaculture can be summarized in to marine bio-prospecting and bioprocess technology, marine genomics and proteomics, marine animal and plant cell culture technology, biotechnological interventions in aquatic animal health management, high health brood stock development, conservation of marine genetic resources and marine algal biotechnology.

Marine bio-prospecting and bioprocess technology

With more than two decades of history, marine bio-prospecting has yielded a few drugs of human application demonstrating the existence of rich biodiversity which can be tapped during the years to come. The focus has been so far on human health, but a paradigm shift in its focus is required should the marine fisheries and aquaculture to be benefitted out of the resources. Bio-prospecting should focus on compounds and molecules required for maintaining health of aquatic animals and protecting them from pathogens, even curing diseases. The challenge is to have compounds which do not interfere with human health on consumption. To make it economically viable a new range of less expensive bioprocess technologies and downstream processes must be visualized. Metabolic engineering for enhanced production, recombinant DNA technology for gene products and synthetic biology for translocation and establishment of the whole production process in a convenient expression system are the exciting avenues to be explored.

Marine-genomics and proteomics

The candidate species of aquaculture should be well defined in terms of its genomics in order to subject them to genetic improvement programmes for growth, disease resistance and tolerance to environmental variations. Whole genome sequencing by way of new generation sequencing and transcriptomics pave the way in delineation of the species which would help develop appropriate culture practices with sustainability in terms of stress reduction. Marine protein engineering, protein-protein interactions, functional proteomics, metabolomics and system biology are the fascinating and challenging areas of the future. The marine organisms are also potent source of antimicrobial compounds and can be used for

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exclusion of pathogens in aquaculture. Besides they are the source of antimicrobial peptides (AMP), the endogenous antibiotics which exhibit antibacterial, antifungal, antiviral and antitumor properties and their potential to overcome bacterial resistance make them promising candidates for the development of therapeutics inclusive for aquatic animals.

Marine animal and plant cell culture technology
Requirement of animal cell cultures/cell lines is not for aquatic animal virus isolation alone but for application as tools in bioassays and toxicology and as source of an array of secondary metabolites of biomedical importance. Pluripotent stem cells serve as tools to mediate gene transfer in fishes. Micro-propagation of marine plant tissue paves the way for extensive cultivation of marine plants in marine systems for product development and development of fermentation processes for valuable bio-molecules.

Biotechnological interventions in aquatic animal health management
Biotechnological interventions such as diagnostics (nucleic acid and antibody based), prophylactics (probiotics, immunostimulants and vaccines including recombinant and DNA vaccines), therapeutics (aquaculture grade natural compounds/ molecules), cell penetrating peptides for drug delivery and bioaugmentors for bioremediation of detritus, ammonia, nitrite and hydrogen sulfide demand further expansion and percolation in to real life situations for building up robust and fool proof aquaculture production systems under zero water exchange or recirculation mode to attract massive investment from private sector. A National policy on aquatic animal health management strategy is imminent.

High health brood stock development
Innovations in marker assisted selection of brood stock, molecular breeding, development of specific pathogen free and specific pathogen resistant populations, transgenesis for high health brood stock are the attractive and challenging avenues. Recombinant hormones, hormone antagonists and RNA mediated silencing of maturation and reproduction inhibitory hormone genes offer solutions to the long awaited impediments in domestication of several of crustaceans in aquaculture.

Conservation of marine genetic resource
Marine environment impairment, climate change and overexploitation pose threat to the marine genetic resources. While reversal of the above situations are essentially to be undertaken globally, biotechnological interventions, apart from establishment of marine protected areas and implementation of responsible fishing, need to be relooked for concerted action.

Marine algal biotechnology
In aquaculture perspective marine micro algal biotechnology focuses on live feed organisms of varied dimensions to suit to the requirement of feeding larvae of different species. Starting from their isolation from marine environment to the product development, a whole lot of bioprocess (inclusive of photo-bioreactors) with effective downstream process stands out to be attempted in support of seed production technology. These marine microalgae offer to deliver bioactive molecules of nutritional and physiological importance.

Global competitiveness

Indian aquaculture sector has to gain global competitiveness in terms of quantity and quality. This should be inclusive of environment health especially the aquatic system.

Marine Fisheries & Management

Track 1

Sea surface height based Potential Fishing Zone predictions - Preliminary observations from Andaman Islands

Dam Roy, S., P. Krishnan, A. Anand, Raymond Jani Angel, R. Kiruba Sankar*

Central Island Agricultural Research Institute, Port Blair 744 101, Andaman and Nicobar Island, India.
Email: rkirubasankar@gmail.com

Potential fishing zone (PFZ) advisories based on chlorophyll and sea surface temperature (SST) have major limitation in Andaman and Nicobar Islands since the advisories are discontinuous and interrupted due to cloud cover over 6 months in a year. Sea surface height (SSH) is another important parameter like chlorophyll and SST to detect fishing ground using altimetry based data by locating eddies and upwelling regions. Unlike SST and chlorophyll, altimeter readings are not influenced by cloud cover. The relationship between eddies, fish catch and chlorophyll maps were studied to augment the PFZ advisories using altimetry data from SARAL ALTIKA. Under this study, 12 major fish landing centers (6 from South Andaman; 2 from Middle Andaman and 4 from North Andaman) were covered during 2013-14 and data with respect to crafts and gears employed, baits used, major landings and economics of operation were collected within and outside PFZ. There are 6 types of major gears i.e. ring net, gill net (drift and bottom), anchor net, trawl net, hand line and long line operated by the fishermen of these Islands. Maps of Sea Level Anomaly (MSLA) and geostrophic current data from AVISO were used. Positive anomalies (anticyclonic/warm core eddies) and negative anomalies (cyclonic/cold core) were identified by contouring the SLA maps. Commercial catch-effort data from gillnet, ring seine and long lines were plotted on SLA maps. Contemporary MODIS Aqua 8 day Chlorophyll maps were used to examine increased primary productivity in terms of chlorophyll. The following are preliminary observations made under the study as, eddies, mostly anti-cyclonic / warm core, are seen regularly in the vicinity of ANI. The productive regions are warm core (WC) eddy peripheries, cold core (CC) eddies and eddy interaction areas (CC-CC; CC-WC; WC-WC). Consistency in increased chlorophyll is being studied along the eddy regions as warm core (WC) eddy peripheries, cold core (CC) eddies and eddy interaction areas (CC-CC; CC-WC; WC-WC).

Large pelagic fishery exploited by traditional fishermen at Tharuavaikulam, Tuticorin, south-east coast of India - An example of successful diversification of fishing

Sivadas, M.*, E.M. Abdussamad, S. Mohamed Sathakkathullah, K. Suresh Kumar and K. Kannan

Central Marine Fisheries Research Institute, Tuticorin Research Centre, South Beach Road, Tuticorin 628 001, Tamil Nadu, India. Email: sivadasmadhav@yahoo.com

Multiday drift gill net fishery targeting mainly deep sea tuna has been practiced by fishermen of Tharuvaikulam village near Tuticorin since 2000. In addition to tuna, other large pelagic resources are also caught in this. The operation is throughout the year. One of the highlights of this fishery is that the fishermen resorted to this fishing after converting their trawlers into drift gill netters. Now this is the only place in Tuticorin district where multiday drift getting is practiced throughout year. At present there are around 70 units operating from here though the number of units landed per day is below 30 only considering the facilities for disposal and marketing. The present paper deals with a detailed study on the large pelagic landed by drift gill net fishery based on the data collected during the year 2011 to 2013.

The trawler type boat locally called as 'launch' is fitted with inboard engines of 108-110 hp. Majority of these boats were fitted with mechanical winches during 2013 for hauling the net. Each piece of drift gill net of 120-140 mm mesh size is 50 m length and 6 to 8 m breadth. In a unit, 50 to 60 number of pieces will be joined together to make single net. The fishing is during night and there will only be one operation in a day but if there are more shoals, they may operate one more time. One fishing trip lasts for 5 to 6 days. But according to fishermen, total quantity of fish targeted is one tonne and if they get it on the first day itself, they will return to the landing centre. There are mainly two fishing grounds, one is off Manappad and another is off Mandapam. There is also another ground straight off Tuticorin. The depth of the ground varies from 25 to above 300 m. The fishing off Manappad is carried out during June to September-October which is also the main fishing season. During the rest of the period, fishing is conducted either off Mandapam or off Tuticorin.

The average total production of large pelagics comprising tuna, seer fish, bill fishes, dolphin fish and carangids during the period 2011 to 2013 was 3609 t which formed 85 % of the total catch by drift gill net. Average tuna production was 2663.7 t with a CPUE of 561.3 kg. The seer fish production was 444.87 t with a CPUE of 93.7 kg and that of carangid was 96.8 t with a CPUE of 20.4 kg. The bill fish production was 362 t with a CPUE of 76.3 kg and that of dolphin fish was 41.9 t with a CPUE of 8.8 kg. Tuna fishery was comprised of *Thunnus albacares* (43.8%), *Katsuwonus pelamis* (29%), *Euthynnus affinis* (22%), *Auxis thazard* (3.4%), *A. rochei* (0.7%), *Thunnus tonggol* (0.7%), *Sarda orientalis*

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(0.3%) and *Gymnosarda unicolor* (0.01%) and among these, the first four species occur in the fishery throughout the year. The seer fishery was comprised of *Scomberomorous commerson* (79 %) and *Acanthocybium solandri* (21%) of which the former occurred throughout the year. The bill fishes were comprised of *Istiophorus platypterus* (44 %), *Istiompax indica* (47 %), *Tetrapterus* spp (3 %) and *Xiphias gladius* (6%). The dolphin fish was almost fully comprised of *Coryphaena hippurus*. Peak period of abundance was June to December and January to March for *K. pelamis* and March-April and June to December for *T. albacares*, May to November for *E. affinis* and January to April and August for *A. thazard*. The peak season for *I. platyperus* was March-April and June to December. For *I. impax*, it was January to April and September to December and for *X. gladius*, June and October to December formed the peak season.

Table.1 Size range (body length for bill fishes and FL for others), mean and mode of the main species landed.

Resource	Species name	Size range(cm)	Mode	Mean
Tuna	*T. albacares*	28-186	68&88	74.3
	K. pelamis	28-78	48	50.5
	E. affinis	20-70	48	44.5
	A. thazard	24-54	36	36
	A. rochei	20-30	24	24.8
	T. tonggol	44-94	58	60
	S. orientalis	28-60	46	43.5
Seer fish	*S. commerson*	26-152	68	81.6
	A.solandri	76-156	110	109.9
Bill fish (Lj FL)	*I. indica*	180-344	230	240.6
	I. platypterus	110-216	178	173.8
	X. gladius	56-212	124	115.8
Dolphin fish	*C. hippurus*	34-112	84	73.6

In *Thunnus albacares*, though smaller size groups were present in all the months, size groups above 100 cm were more during January to May and December. In *Katsuwonus pelamis*, smaller size groups below 38 cm were more during the months of August to October. 11-53 per cent of the landings were above 64 cm during the months January-May. Size groups above 60 cm were more during June to August. However, in *Euthynnus affinis*, smaller size of groups dominated during the months June-December. In the case of *S. commerson*, 91% of the fishes landed Size groups above 112 cm were caught during June to September. The food of all the tuna species was dominated by fishes.

The length weight relationship was W= 0.050844 L$^{2.72}$for *K. pelamis*, W= 0.014767 L $^{3.0}$ for *E. affinis*, W= 0.032118 L $^{2.8}$ for *T. albacares* and W=0.0123 L 3.0 for *A. thazard*. The size at first maturity of *T. albacares*, *K. pelamis* and *E. affinis* were 81 cm, 43 cm and 44 cm respectively. The impact of fishing using the prediction analysis (T&B) showed the increase of yield and value with the increase in effort implying that the stock of *K. pelamis*,is not adversely affected by fishing. However there was considerable reduction in SSB with increase in effort especially after f-Factor 3. In *Euthynnus affinis*, the analysis showed that MSY and MSE were attained at an F-factor of 1.5 indicating that the present fishing is well within safe level.

A GIS propped methodology for the reconstruction of disaggregated catch and effort spatio-temporal series of Indian marine capture fisheries

Jayasankar, J., T. V. Sathianandan, K. G. Mini, Somy Kuriakose, Wilson T Mathew, Vinay K Vase, Kathireddy Syamala and Grinson George*

Central Marine Fisheries Research Institute, Kochi 682 018, Kerala, India. Email: grinsongeorge@gmail.com

Indian marine capture fisheries has been progressing placidly since the late sixties and is yet in the status of being more subsistence based rather than entrepreneurial. With the global policies targeting more on fishable surplus, pooled resources and larger stock domains, Indian fishers have to be more informed of the availability and extent of exploitation on a regional format. Towards achieving this, a robust broad-based restructuring of catch and effort series of data at varying granularities both spatial and temporal scale is a necessity. CMFRI has been pioneering the estimation of landings and the efforts expended with standardized procedures since 1950's. However with the changing scenario, there is a need to reconstruct the catch and effort series on a more disaggregated matrix. Further the resource availability vis-à-vis prediction for the foreseeable future also occupies place of prominence in the planners mind.

This work highlights a synthetic procedure which combines the historic catch and effort series digitized since 1985 with varying levels of disaggregation, and the relevant concomitant variables to attain monthly time series of resource based data. Upon disaggregating the datasets an effort has been made to standardize the efforts at the lowest possible homogeneous granularity and standardized efforts based on nominal ones have been computed for select resources. Based on the standardized effort series, time series catch rate has been reconstructed at a standard granularity.

Further with passive geo-referencing, a distinct possibility, a unique protocol has been developed and tested by simulation to identify the spatial disaggregation of prospective grounds of select zones by combining discrimination functional involving habitat based depth zones and the presumptive latitude-longitudes of the fishing ground. The resultant spatial series was co-integrated with the temporal catch and effort series to arrive at a disaggregated composite spatio-temporal series of fish catch data. With the training of the datasets for more periods, the procedure can be used to back-cast the historic time series also.

The reconstructed series were uploaded onto a GIS and thematic scenarios were created and compared with the existing similar reports on trends and availability/ scarcity of fishery resources in coastal waters.

Spatial study of catch and effort from fishing vessels to provide policy decision support for fisheries management

Dineshbabu, A. P.*, and Sujitha Thomas
Central Marine Fisheries Research Institute, Mangalore Research Centre, Hoige Bazar, Mangalore 575 001, Karnataka, India. Email: dineshbabuap@yahoo.co.in

At present the subject of fisheries is in the state list under Article 21 of the Indian Constitution. Management and control of coastal fisheries is vested with the maritime states and union territories. At the same time the Union Government carries out management and control of the fishing activities beyond territorial limits in the EEZ which is practically at present restricted to deep sea vessels alone. The Comprehensive Marine Fishing Policy of Ministry of Agriculture, Government of India released in 2004 reviewed the present status of fishery regulation in coastal waters and recognized that, though the Marine Fishing Regulation Acts (MFRA's) of coastal states and UT's have adequate provisions for management of resources and fishing operations, it is often found falling short of effective implementation. It is also observed that the exploitation of living resources within 50 metres depth zone is showing symptoms of depletion and in certain belts in the inshore waters it tends to cross optimum sustainable levels.

In light of these serious concerns, a spatial study of catch and effort distribution in existing fishing grounds were carried out by analysing the GPS data from commercial trawler operated as a sampling boat. GIS software was used for the mapping of fishing effort and fish catch from different geographical area of fishing. The data collection was from the traditional path of the trawler (without any cruise design) as per their knowledge of fish availability. The data collection was designed to understand the extension of fishing ground off Karnataka especially looking into the administrative boundaries like 12 nm from the shore and to know the status of fishing pressure in depth zone to 50 m, 100 m and beyond. Percentage of catch from territorial waters and beyond were also analysed to understand whether the major percentage of fish caught is coming from the area of jurisdiction of Karnataka state. During the period 2007-2013 1,438 days of fishing cruises was done by the sampling trawler from Mangalore to Ratnagiri coast of Maharashtra to Calicut coast of Kerala covering an area of 150-200 m depth zone every year. Of the 1,438 days of cruises, it was found that only 28% of the cruises are falling within the territorial waters of 12 nautical miles of the States (not only Karnataka) and remaining 72% is operated waters beyond territorial waters (Fig.1). The present study endorses the concern of the MOA that 50 m zone is highly exploited and the study showed that during 2007-2013, 60% of the fishing pressure was concentrated within the 50 m depth zone showing an additional fishing pressure of 32% between territorial waters and 50 m depth zone. When 100 m depth was taken as a criteria for fishing pressure estimation it was found that 86% of the fishing pressure is falling within 100 m depth zone and only 14% of the fishing

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was found to take place beyond 100 m depth zone. The study throws light on the need for the revision of a criteria of area of jurisdiction of each State to bring maximum possible area of fishing under the jurisdiction, if jurisdiction zone is based on depth, 50m depth or 100 m depth will give the scope of management of majority of the fishing operation for the maritime States along west coast of India. When the depth is taken as the criteria for redefining the jurisdiction, it was estimated that 50 m depth zone off Karnataka is falling within 25 to 30 nautical miles from the shore and 100 m depth is 40 to 50 nm off Karnataka coast.

As far as fish catch of the trawlers are concerned, it was estimated that in Karnataka more than 70 % of the catch was brought from the waters beyond 12 nautical miles (Fig. 2). The present study conducted along south west coast of India clearly indicate that trawlers from Karnataka operated in the waters off adjacent states Kerala, Goa and Maharashtra and this is the case with almost all multiday trawlers operated from different states also. This finding endorses the concerns flagged in the Comprehensive Marine Fishing Policy (2004), that there are increased incidence of straying by small-mechanised boats into each other's territorial waters and consequent confiscation and arrest of crew. On the basis of the above findings to avoid conflicts between fishermen and states and also to bring all fishery operations under management umbrella, a regional fishery regulatory body in the auspices of Central Government is extremely essential. Further spatial studies of catch and effort from the trawlers operated from different states need to be undertaken to understand the national scenario so that our management policies can be comprehensive and country can ascertain that the fish production from Indian waters is coming from well managed fishery. The present study also throws light on the utility of the GIS based spatial studies of fisheries to provide decision support system for policy revisions and policy making and also the need to intensify such spatial studies in future for the effective management of marine fisheries in India.
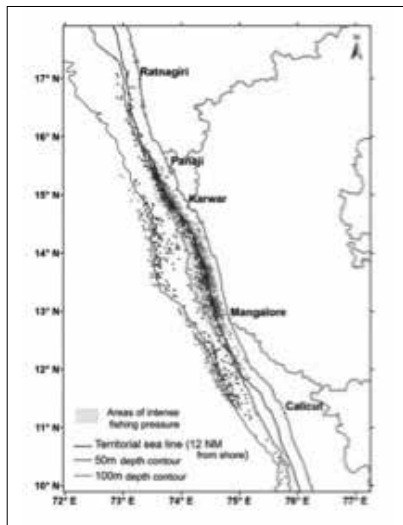
Fig.1. Distribution of fishing effort mapped off Karnataka during 2007-2013
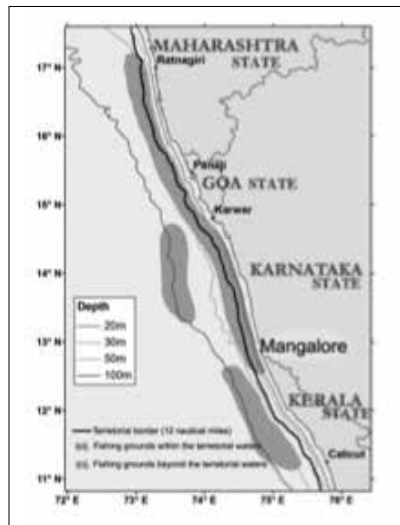
Fig.2. Mapping of fishing grounds and catch to find out the contrition of territorial waters and beyond.

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Prediction of future catch ranks for marine fished taxa along Karnataka coast, India using Markov chain analysis

Veena, S.*, K.S. Mohamed, T.V. Sathianandan, P. U. Zacharia, P.K. Asokan, P. K. Krishnakumar, K.P. Abdurahiman and R.N. Durgekar
Central Marine Fisheries Research Institute, Visakhapatnam Regional Centre, Visakhapatnam 530 003, Andhra Pradesh, India. Email: veenashettigar@yahoo.co.in

Out of the 579 species which are recorded as fished in Karnataka during the 1960-2008 period, only 9% were in the common category comprising of 53 species/groups. Long–term trends in the commercially caught species were studied, based on which the probability of ranks in future was predicted using Markov Chain analysis. Only 3 species are known to have held the number 1 rank and will continue to hold it in the future. Oil sardine and mackerel are likely to continue and dominate the catches in future also, although oil sardine has higher probability to be at Rank 1 position (Fig.1). Many groups, such as shrimp, speckled shrimp, cuttlefish, squid, sharks, catfish and whitefish are likely to remain in the same rank classification in future. Ribbonfish have high probability to decline in catch and rankings because at present these species are being overexploited. On the other hand, anchovies (*Stolephorus sp*.) and mantis shrimp are likely to increase in catch and rankings. Higher probability of threadfin breams, *Nemipterus sp*. occupying the ranking of 1-5 is noted. Cephalopods are predicted to continue to dominate the fishery in future since both cuttlefish and squid which hold high rank below 10 during 2008 are likely to occupy rank of 1-10 in future years. Among elasmobranchs, there is a chance of improvement in the fishery of spadenose sharks from below 50 rank and blacktip shark from below 60 according to the prediction model.

When grouped according to their probability ranking it was seen that 18 species will improve their fishery ranking while 23 will retain their ranking and 6 will deteriorate in their ranking. Some of the species which will improve in their ranking are *Rastrelliger kanagurta, Cynoglossus macrostomus, Arius sp., Scoliodon laticaudus, Carcharhinus sp., Parapenaeopsis stylifera, Metapenaeus dobsoni, Metapenaeus affinis, Fenneropenaeus merguiensis* and *Portunus pelagicus*. Some of the species which will retain their present ranking in future were the *Sardinella longiceps, Nemipterus sp., Pampus argenteus, Parastromateus niger, Lactarius lactarius, Penaeus monodon, Metapenaeus monoceros, Fenneropenaeus indicus, Portunus sanguinolentus, Sepia sp*. and *Loligo duvauceli* were also seen to retain their ranks in the future production. *Trichiurus sp., Saurida sp., Scomberomorus commerson, S. guttatus, Mugil cephalus* and *Anodontostoma chacunda* were predicted to have a probability of deteriorating in their catch ranks.

Marine catfish, whose rankings have slipped from 5 to 160 in recent years in Kerala (Mohamed *et al*. 2009) and from 3 to 104 in Karnataka and has recovered to 34th ranking in recent years as seen in present study. The prediction of future

status of the species in the fishery using Markov Chain analysis helps to monitor the species which have deteriorated or on the verge of deterioration and help to monitor the status of the marine fishery in Karnataka.
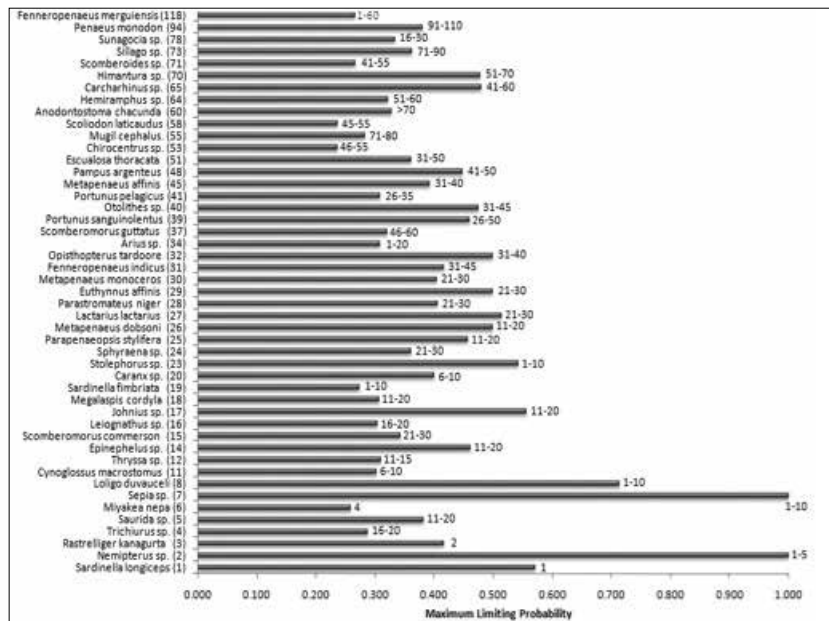
Fig. 1. Markov Chain analysis for common marine taxa showing maximum of the limiting probabilities. Figures besides bars indicate the predicted rank classification of that species in future. 2008 ranks are given in parenthesis on the x–axis.

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MECOS 2 |MFMO 06

Inter-annual variations noticed in selected oceanographic parameters off Kochi (south west coast of India) in relation to changes observed in the availability as well as abundance of major small pelagics

Kripa, V.*, D. Prema, R. Jeyabaskaran, L.R. Khambadkar, A. Nandakumar, P. S. Anilkumar, T. V. Ambrose, Preetha G. Nair and V. N. Pillai
Central Marine Fisheries Research Institute, Kochi 682 018, Kerala, India. Email: vasantkripa@gmail.com

The availability as well as abundance of selected small pelagics along Kerala coast (south west coast of India) is highly variable during the past three decades. During the three decadal studies (1980-2012) there have been several periods of abundance as well as population crashes noticed in the fishery for oil sardine. The O-group recruitment to the fishery is controlled either by early wind driven

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upwelling or early intensification of the equator-ward coastal current and consequent upsloping of isopycnals. Contrary to earlier predictions, the oil sardine fishery along Kerala coast has shown a phenomenal increase in landings after 2000 and has reached a record high during 2012. Possible reasons for this change are being evaluated in this paper.

Table: Relationship between sea level (High & Low), bottom water temperature (BWT) and dissolved oxygen (DO) at 10 m depth Off Kochi (1990-2000)

Year	Sea level		BWT (oC)		DO (ml l-1)	
	High	Low	High	Low	High	Low
1990	7003 (Feb)	6834 (Sept.) 6846 (July)	30.12 (April)	21.45 (Aug.)	3.56 (April)	0.68 (Aug.)
1991	7035 (Mar.)	6851 (Sept.)	30.1 (May)	24.25 (Sept.)	4.27 (Feb)	1.65 (Sept.)
1992		6834 (Aug.)	30.85 (May)	23.80 (Sept.)	3.72 (May)	0.94 (Sept.)
1993	7030 (Jan.)	6811 (Aug.)	31.70 (Apr.)	22.8 (Aug.)	3.97 (Apr.)	0.95 (Aug.)
1994	7112 (Feb.)	6857 (May)	30.1 (Apr.)	24.00 (Aug.)	3.37 (Feb.)	0.68 (Aug.)
1995	7035 (Apr.)	6874 (Aug.)	30.6 (Apr.)	22.97 (Aug.)	3.97 (Apr.)	0.90 (Aug.)
1996	7082 (Jan.)	6869 (Aug.)	29.5 (May)	23.10 (Aug.)	4.20 (June)	0.48 Aug.)
1997	7054 (Jan.)	6854 (Aug.)	30.0 (Mar)	24.3 (Aug.)	4.73 (Mar.)	2.72 (Aug.)
1998	7002 (Feb.)	6952 (Aug.)	31.4 (Apr.)		4.76 (May)	
1999	7143 (Feb)	6833 (Sept.)	30.0 (Mar.)	24.5 (Aug) & 24.7 (Sept.)	4.35 (May)	1.41 (Sept.)
2000	7053 (Feb.)	6831 (July)	28.9 (Feb)	22.4 (July)	4.53 (Feb.)	0.68 (July)

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MECOS 2 |MFMO 07

A comparative predictive analysis of logistic regression, classification and regression tree (CART) and neural networks (NNS) models for predicting catch per unit effort (CPUE) abundance of fish: a case study in Gujarat coastal region

Vinod K. Yadav*, J. Adinarayana, S. Jahageerdar, V. Ramasubramanian, Vidya S. Bharti and M. Krishnan
Central Institute of Fisheries Education (CIFE), Mumbai 400 061, Maharashtra, India.
Email:vinod_iasri@yahoo.co.in

Fish catch rates are expressed as catch per unit effort (CPUE) which is a fishery performance index representing the success of fishing from commercial fishery statistics. CPUE values are calculated as the total catch of fish (in kg per fishing effort). Numerous articles comparing performances of statistical and Neural Networks (NNs) models are available in the literature, however, very few involved Classification and Regression Tree (CART) models in their comparative studies.

We perform a three-way comparison of prediction accuracy involving logistic regression (LR), multi-layer perceptron (MLP) Neural Networks (NNs) and CART models using a binary dependent variable (CPUE abundance as low or high) and a set of continuous and categorical predictor variables describing seasons, latitude, longitude, gear type, fishing hours and chlorophyll-a concentration. A dataset on CPUE abundance of the Gujarat coastal region was obtained for the period December 2007 to December 2009 from Indian National Centre for Ocean Information Services (INCOIS) Hyderabad. Over all it was observed that CART predicting the CPUE abundance accurately (78.2%) than Logistic regression (73.1%) and ANN (70%). Performances of classification techniques were compared using received operating characteristic (ROC) curve. ROC plots were used to compare model performance on test data at a range of thresholds and it was found that CART and LR outperformed ANN. These are preliminary results and require multi or related variables in spatio-temporal mode for better CPUE predictions.

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MECOS 2 |MFMP 01

Neural network and Arima models for forecasting oil sardine fishery of Kerala

Somy Kuriakose*, K.G. Mini, T.V. Sathianandan and J. Jayasankar
Central Marine Fisheries Research Institute, Kochi 682 018, Kerala, India. Email: somycmfri@gmail.com

The oil sardine (*Sardinella longiceps*) fishery of India is a commercially important fishery due to food value and industrial uses. It contributes significantly to the marine fish landings of India and forms the mainstay of Indian pelagic fisheries. Along the Indian peninsula, the resource has been predominant along the southwest coast comprising the maritime states of Kerala, Karnataka and Goa. Kerala accounts for more than half of the landings from India with an average landings of 2.8 lakh tonnes during 2009-13. With a coastline of 590 km, there are 187 marine fish landing centres spread over the nine coastal districts of Kerala. During the last few decades the oil sardine landings has increased several-fold, mainly due to the introduction of mechanized fishing vessels, their substantial growth in the number and efficiency and use of seine nets. The landings reached an all-time high estimate of 3.99 lakh tonnes in 2012, but showed a decline in 2013 to 2.47 lakh tonnes.

Modelling and forecasting of fisheries catches play a central role in fisheries management as it is necessary to predict abundance or biomass changes. The dynamic nature of the fishery suggests that stochastic models are appropriate to obtain a quantitative assessment of the stocks status and reliable predictions for the future. Two forecasting techniques, ARIMA and Neural Networks are evaluated on the basis of their efficiency to provide accurate fits and predictions. ARIMA models assume that a time series is a linear combination of its own past values and current and past values of an error term. They capture the historic autocorrelations of the data and extrapolate them into the future. In Neural Network modelling, a non-linear mathematical structure representing the complex processes relates the

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inputs to the outputs of a system. Time series data on monthly estimates of oil sardine landings from Kerala during 1992-2013 were used for the study.

Different models were fitted and the measures of accuracy were computed and compared for the original time series and ARIMA $(3,0,1)(2,1,1)_{[12]}$ was found to be best suitable model. A feed-forward network with one hidden layer, with 17 lagged inputs and 9 nodes in the hidden layer was identified as the most appropriate model for predicting monthly oil sardine landings. The results reveal that NNAR (17, 9) model is the best performer overall, characterized by a higher number of stable forecasts, and forecasts with higher precision and accuracy, than the ARIMA model (Fig.1)
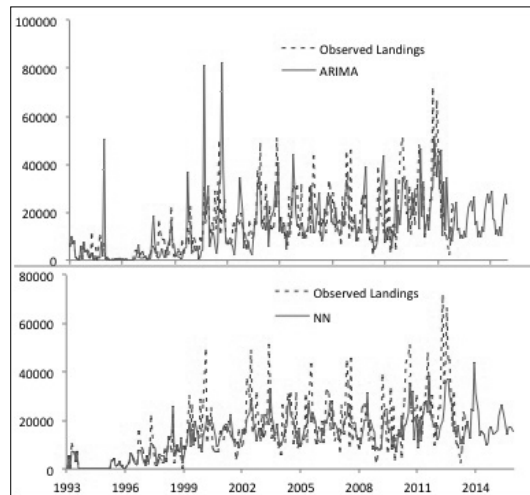
Fig.1 Observed Landings and forecasted values using different models

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MECOS 2 |MFMP 02

Prediction of marine fish landings along the northeast coast of India using neural network models

Mini, K.G *, Somy Kuriakose, T.V. Sathianandan and J. Jayasankar
Central Marine Fisheries Research Institute, Kochi 682 018, Kerala, India. Email: minikg02@gmail.com

The northeast coast with a coastline of 638 km, comprising the maritime states of West Bengal and Odisha contributes about 10% to the India's marine fish production. In 2013, the marine fish landing in northeast coast was about 3.86 lakh tonnes with West Bengal contributing 68% and reminder from Odisha. Of the 132 marine fish landing centres spread along the coast, 73 belongs to Odisha. Though, there is a quantum jump in the landings over the past decade from 2000 onwards and reached its peak in 2011, the rate of increase was in the reverse direction during the last two years. The major share of the landings was by mechanized sector (70.4%) followed by motorized sector (27.1%) and the rest

2.5% was contributed by non-motorized. Trawlers, gillnetters and bagnetters are commonly used in the mechanized sector while plank built boats, canoes and catamarans are used in the artisanal sector. Gillnets, bagnets and hooks & lines were the important gears in the motorized sector.

Analysis of time series data and the evolving models has become an important tool for predicting the nature of fishery in the long-run. Compared to traditional modeling approaches, advanced techniques such as neural networks can be used to assess the status and general trend of a given fish landings time-series with increased reliability and accuracy. The present paper applies the artificial neural network (ANN) approach for predicting the marine fish landings of northeast coast. The method is based on training an ANN with auto regression using input data onquarter-wise marine fish landings during 1985-2013. The landings for the coming year is estimated using the trained ANN with the current set of data. A total of 20 networks are fitted, each with random starting weights. The network is trained for one-step forecasting. The fitted model is a feed-forward network NNAR (13,7,1) with 13 lagged inputs and one hidden layer with seven neurons. Multi-step forecasts for next ten years are computed recursively (Fig.1)

The resulting model correspond well to observed values.
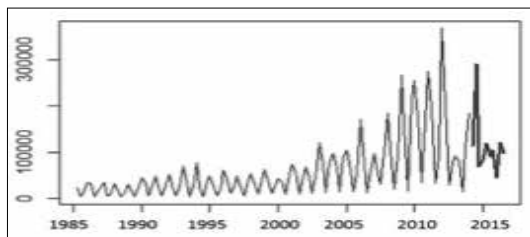
Fig.1. Forecasts from a neural network – NNAR (13,7,1)

Exploitation status of *Perna indica* along the Vizhinjam coast

Anil, M.K. *, Geetha Sasikumar, K.T. Thomas and N. Ramachandran
Central Marine Fisheries Research Institute, Vizhinjam Research Centre, Thiruvananthapuram 695 521, Kerala, India. Email:mkanil65@gmail.com

The brown mussel *Perna indica* has a very restricted distribution along the southwest coast India from Quilon to Cape Comorin. A traditional sustenance fishery exists for the brown mussel off Kovalam near Kanyakumari, Muttom, Kadiapatanam, Colachel-Kodimuna, Vaniakudi-Kurumpana and Melemidalam-Enayam along the west coast of Tamil Nadu. Along the south Kerala coast, they are found off Pulinkudi, Mulloor, Vizhinjam, Avaduthura-Kovalam, Valiathura, ThazheVettoor and Odayam near Varkala. Among these mussel beds, Kadiapattanam, Colachel,

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Enayam, Pulinkudi, Mulloor and Vizhinjam are the major centres for mussel fishery.

Mussels are mainly attached to the sub-tidal rocks and to a lesser extent on the intertidal hard substratum in all centres. The average landing of brown mussel at Vizhinjam during 2008-13 was 754 t, ranging from 490 t in 2008 to 1,181 t in 2012 (Fig.1). Fishing was observed year-round off Vizhinjam-Kovalam beds, whereas, in Pulinkudi-Mulloor, stretch, mussel fishery was only during the post-monsoon and pre-monsoon periods. The peak-fishing period was observed during October to November in the region. Considering the growing demand for mussel in Kerala, it has become a necessity to monitor and manage this resource. Information on the population characteristics of this species is meagre and hence an attempt to estimate the population parameters and status of exploitation of *P. indica* from selected areas along the Vizhinjam coast of India was carried out.

Length based analysis of the samples collected during the period 2012-13 was carried out. Per recruit analysis using 'YIELD' software was carried out with assumptions of constant recruitment, knife edge selection deterministic. The von Bertalanffy growth parameters, L_∞ and K were estimated as 12.6 cm and 0.72 respectively. Estimated total mortality (Z), natural mortality (M) and fishing mortality (F) were 3.64,1.524 and 2.12. Per recruit analysis yielded $F_{max} = 8.33$; $F_{0.1} = 1.57$ and $F_{0.2SSB/R}$ (initial) $= 2.27$.The size at 50% maturity ($L_{m50\%}$) was estimated at 6.0 cm; the optimum length (L_{opt}) at capture was estimated at 7.39cm and the L_{mean} at 7.92 cm (Fig. 2). Since the mean size was larger than the $L_{m50\%}$ and Lopt it is indicated that the catch is largely based on mature mussels and that the fishery is not at risk of recruitment and / or growth overfishing.
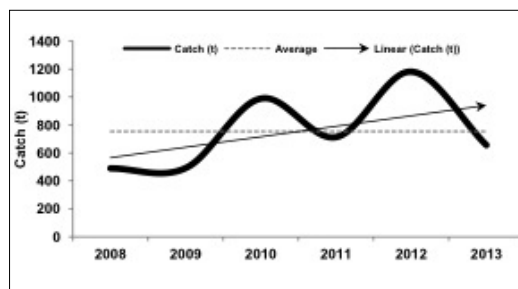
Fig. 1 Catch trend of *Perna indica* along Vizhinjam coast
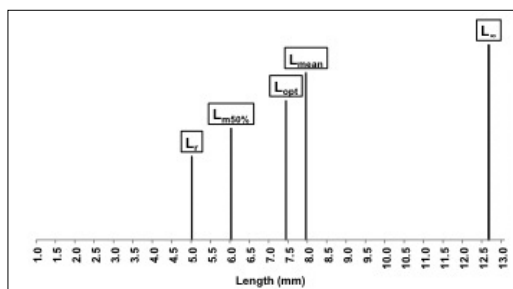
Fig. 2.Size-line graphs of *Perna indica* showing life history landmarks

MECOS 2 |MFMP 04

Trophodynamics of brushtooth lizardfish *Saurida undosquamis* along Chennai coast

Gomathy, S.* and E. Vivekanandan
Central Marine Fisheries Research Institute, Madras Research Centre, 75, Santhome High Road, Chennai 600 028, Tamil Nadu, India. Email: gomathycmfri@gmail.com

Information on trophodynamics is necessary to understand the functional

relationship between organisms in an ecosystem. Collection of data on, who feeds whom and how much, is fundamental to develop ecological models. Investigations on the trophodynamics of predators are important to know their top-down control on the prey in the food web. To gain an insight into the dynamic dietary relationship with its own and other species, the gut content of the predatory brushtooth lizardfish *Saurida undosquamis* was studied along Chennai coast (southeast coast of India) during January 2006-December 2008. Data on several trophic attributes were collected with reference to two variables, namely, body size (small, medium and large), and season (post-northeast monsoon (PNE); summer (SUM); southwest monsoon (SW); and northeast monsoon (NE)).

The following morphological and morphometric measurements/counts/analysis were made following standard methodologies: fish total length and weight, jaw length, dentition, teeth, mouth gape, gill rakers, stomach length and relative stomach length (RSL). Condition index was determined by allotting points to percentage stomach condition to the total number of stomachs from empty to gorged. Detailed quantitative and qualitative analysis of stomach contents up to the level of family/genus/species was made following standard procedures. To find out the relative importance of prey items, dietary overlap, trophic position, indices such as Index of Relative Importance (IRI), niche breadth and trophic level (TrL) were calculated.

The predatory feeding behaviour of *S. undosquamis* was aided by morphological adaptations of the fish, namely, the high body depth-total length ratio of 1: 8.3, vertical opening of mouth (20% of the length of the fish), mouth gape area of 610 mm2, numerous, small, pointed needle-like canine teeth, short and hard spine like gill rakers (124 in lower arch), and short relative stomach length of only 0.50. These morphological features indicate the capacity of the lizardfish to capture prey of larger body size and gradually squeeze it into the short oesophagus.

The food of *S. undosquamis* consisted of prey types belonging to 13 groups (Orders), 44 genera and 58 species. Perciformes and Clupeiformes were the major prey items in terms of frequency of occurrence (FO), Abundance (A) and Biomass (B) and Index of Relative Importance (IRI) (Perciformes:1282; Clupeiformes: 938). The Ln% IRI of these two prey types was higher than the other prey (Fig.1). Decapods were the important secondary prey of *S.undosquamis*. The niche breadth of 2.78 indicated the narrow choice of food for the fish. The trophic level of 4.32 showed that the fish is a top predator.

The three size groups of the lizardfish predated upon the same prey taxa, indicating dietary overlap among size groups. With ontogenetic development, however, the feeding strategy of large individuals of lizardfish was characterised by significantly low stomach condition index (25.7% lower than the small size group), narrow niche breadth (1.85 compared to 4.10 of small-size group in the lizardfish), higher trophic level (4.42 compared to 4.21 of small-size group) and capacity to predate upon relatively larger prey, but sporadically in smaller numbers. Cannibalism was noticed in all size groups and was higher in large-sized fishes.

Comparison between the four seasons showed that Perciformes remained as the specialised prey of *S.undosquamis* in all the seasons. However, niche breadth, trophic level and cluster analysis showed that the diet during NE and PNE seasons was different from that of SUM and SW seasons.

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With cannibalism as a foraging strategy, and other ingested prey occupying high trophic levels, the morphometry and high trophic level values determined for all size classes and seasons confirm that *S.undosquamis* is a benthic predator, potentially affecting high trophic level populations by predating on their juveniles. Future dietary studies on high trophic level fishes need to be designed to capture the potentially high seasonal and ontogenetic variability in their diet. This approach will enhance the utility of dietary studies as tools for managing fisheries from an ecosystem perspective.
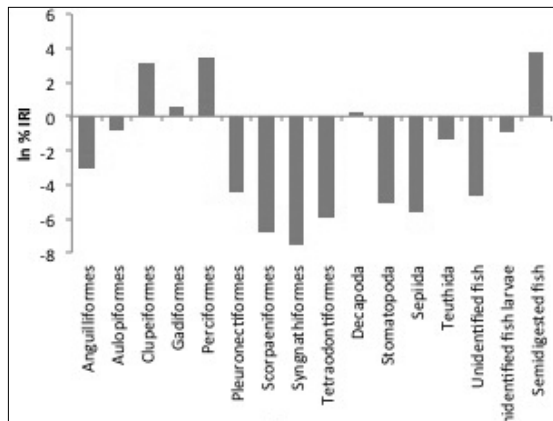
Fig.1 Index of Relative Importance (Ln% IRI) of prey groups of *S. undosquamis* (n = 860) during January 2006 – December 2008

MECOS 2 |MFMP 05

Shore seine fishery with special emphasis on juvenile exploitation along Poovar, south west coast of India

Saleela, K. N.*, A.P. Dineshbabu, B. Santhosh, M. K. Anil and C. Unnikrishnan
Central Marine Fisheries Research Institute, Vizhinjam Research Center, Vizhinjam 695 521, Kerala, India
Email: saleela.ajay@gmail.com

This study deals with seasonal variations in species composition of commercially important fishery resources, catch per unit and hour, juvenile and spawner composition including size frequency distribution of dominant species caught by shore seines along Poovar (Latitude N08°19.938', Longitude E07°02.784'). Poovar is an important traditional fishing centre situated in Thiruvananthapuram district of Kerala along the south west coast of India where shore seine operation is an important fishing activity. Shore seines locally known as 'Karamadi or Kamba vala' are operated using canoes and fibre glass boats (28 to 36 foot) within 5 to 7 m depth along 0.5 to 3 km from the sea shore. The estimated annual average fish landings by shore seines were amounted to 22.5 t caught at a cpu of 76.701 kg and cph of 19.175 kg. So far no study has been conducted on shore seine fishery

pertained to this area. On account of the importance of the fishery, present study was carried out for 2 years from Poovar, during October 2012 to September 2014.

This fishery was mostly supported by finfishes (99%) and represented by 43 species, belonging to inshore pelagic fishes such as anchovies, silverbellies, carangids, sardines, mullets, mackerel, *Saurida*, etc. The fishery was dominated by *Stolephorus indicus* (33.2%), *Sardinella longiceps* (31.1%), *Encrasicholina heteroloba* (13.2%) and *Leiognathus lineolatus* (8.1%) contributing 85% of total fish Landings. The peak fishing season along this coast was observed as post monsoon contributing (54 %) of total fish landings, followed by pre-monsoon and monsoon.The species diversity during different season is discussed. Occurrence of juveniles of commercially important species in the fishery was observed during post - monsoon season when they formed 76.7% of total fish landings by this gear. The study shows shore seines as a destructive gear on account of exploitation of bulk catches of juveniles of commercially valuable fishery resources.

MECOS 2 |MFMP 06

An analysis of the fishing gears and practices of Pulicat lake: The biodiversity perspective

Baby Shalini*, Lita Sunder and K. Mahesh Kumar
Madras Christian College, Tambaram, Chennai 600 059, Tamil Nadu, India.
Email: lita_sunder@yahoo.co.in

Modern fishing gears and practices are the greatest threat to marine ecosystems today. They cause irreversible damage to the vulnerable ecosystems. Destructive fishing methods pose a serious problem as they destroy or degrade important habitats for fish and other organisms. They directly threaten species richness and biodiversity. These catch rears a variety of non-target organisms and capture high proportions of juvenile fish leading to growth exploitation of marine resources and reduced yields.

The biodiversity of Pulicat Lake, the second largest brackish water lagoon is also threatened by fishing activity. The fishery resources are a vital source of food and income to the communities involved in fishing activity at Pulicat Lake. The present study was undertaken to study the fishing gears and practices of the Pulicat Lake. It assessed the development/modernization of gears over the period of time to improve efficiency. The nature of the gears, selective or non-selective was analysed based on the size and species selectivity. From the above observations, the impact of the fishing gears and practices on biodiversity was analysed. This study would help to undertake management measures for sustainable use of fishery resources of the Pulicat Lake.

MECOS 2 |MFMP 07

Enhancement in total fish catches after tropical cyclones (*Phailin* and *Hudhud*) in the northern Bay of Bengal lying adjacent to West Bengal coast

Sourav Das
School of Oceanographic Studies, Jadavpur University, Kolkata 700 032, West Bengal, India
Email: sourav.biooptics@gmail.com

Primary productivity plays an important role in the availability of marine fish stock of oceans while tropical cyclones are found to have short term impact on primary productivity of oceanic water. Very limited studies have been done to verify the impact of cyclone on the total fish catch (as Catch per Unit Effort (CPUE)) especially in the shallow continental shelf waters throughout the globe. Monthly mean of chlorophyll *a* and daily fish catch data (specially before and after the occurrence of cyclones) were compared in the northernmost sector of the Bay of Bengal lying adjacent to the West Bengal coast, covering roughly an area of ~1000 sq. km throughout three annual cycle from 2012 to 2014.

A short term increase in total fish catch (CPUE) in the northern Bay of Bengal (nBoB) after the occurrence of the tropical cyclones -*Phailin and Hudhud* (occurred land fall near Gopalpur, Odisha on 12th October, 2013 and Pudimadaka near Visakhapatnam on 12th October, 2014 respectively) have been reported in this study. *In-situ* monthly composite data for chlorophyll *a* of three consecutive years of 2012 (in this year no severe cyclone occurred in our study region), 2013 and 2014, were compared to examine the short term impact of cyclones on the productivity of the present study area. Generally during a cyclone, vertical mixing of the water column uplifts nutrients and dissolved oxygen to mixed layer depth that results in the increase in chlorophyll *a*. In this study substantial increase in mean chlorophyll-a concentration was observed in Oct 2013 and Oct 2014 in comparison to Oct 2012. Mean chlorophyll concentration in Oct 2012 was 3.12 ± 1.97 mg/m^3, however, in Oct, 2013 and Oct, 2014 it increased to 9.50 ± 2.09 mg/m3 and 7.37± 2.09 mg/m^3 respectively. Following this productivity trend, a substantial increase in total fish catch and CPUE were also observed.

Mean CPUE (kg/hour) in Oct 2012, 2013 and 2014 were observed to be 09.04 ± 04.70, 18.63 ± 11.54 and 15.08 ± 06.17 respectively. The higher primary productivity caused by the tropical cyclones increased the CPUE by 100.08% and 66.81% in Oct 2013 and Oct 2014 respectively than Oct 2012. This observation justifies the fact that tropical cyclone poses a short term strong impact on the total fish catch of the shallow continental shelf coastal water; however, more elaborate studies are required to establish the hypothesis unanimously.

Observations on the fishery of the major large pelagics along the Vizhinjam coast

Jasmine,S*., E. M. Abdussamad, T. A. Omana and Jose Kingsly
Central Marine Fisheries Research Institute, Vizhinjam Research Centre, Vizhinjam 695 521, Kerala, India.
Email : jasminevzm@rediffmail.com

The marine fish landings off Vizhinjam was dominated by pelagic fishes forming almost 83% of the total catch, the major share being contributed by the tunnies. The large pelagics constituted a considerable share to the total fishery and their average annual landing was 2684 t, accounting for 14.7% of the total marine fish landings during the period 2009-2014. Fishery of these resources except coastal tunas are highly seasonal. Commercial exploitation of these resources were mainly by hooks & line, drift gill nets and boat seines operated from motorised crafts. 53% of the total catch was by drift gill net, followed by hooks & line (45.3%) and a nominal share by boat seine (0.86 %) and multiday trawl units (0.342%). The bill fishes *Istiophorus platypterus, Xiphias gladius ,* the tunas, *Euthynnus affinis, Sarda orientalis, Katsuwonus pelamis, Thunnus albacares*; seer fishes *Scomberomorus commersoni and S. guttatus* and the dolphin fish*, Coryphaena hippuruus* were exploited mainly by hooks & line, drift gill nets and multiday units. *Rachycentron canadum* was landed mainly by drift gill net and barracudas were exploited mainly by drift gill net, mechanized hooks & line, boatseine and *roll vala*. Larger tunas constitute 77 % of the catch followed by *Coryphaena hippurus*, bill fishes, seer fish and barracuda. Other groups such as Cobia *(Rachycentron canadum)*, full beaks, *Scomberoides* spp., etc. contribute marginally to the total large pelagic landings. Diet studies indicated that members of the groups are non selective opportunistic predators feeding on variety of pelagic fishes, cephalopods and crustaceans.

Dietary behaviour among the coral reef butterfly fishes in the coastal waters of south east coast of India

Jayanthi, G.*, M. Anand and A. K. Kumaraguru
Department of Marine and Coastal studies, Madurai Kamaraj University, Madurai 625 021, Tamilnadu, India. Email: jayanthimarine@gmail.com

The dietary separation of selected butterfly fishes is described in the present study. Samples were collected from the coral reefs ecosystems of the Gulf of Mannar and Palk Bay region between June 2012 and December 2013 using trap and scoop nets. Five species viz., *Chaetodon decussatus*, *C. leniolatus, Heniochus*

acuminatus C. octofasciatus and *C. plebius* were chosen for the gut content study. Analysis showed that the order of food preference in *C. decussatus* was small crustanceans followed by corals, polychaetes, algae and sand grains. For *C.leniolatus* the preferred item was polychaetes followed by crustaceans, corals, algae sand grains and detritus. Algae was the preferred food for *H. acuminatus* followed by crustaceans, corals, and sand grains. *C. plebius* preyed on corals, followed by sand grains detritus. Amphipods and copepods are the major food for *C. decussatus* where as terebellid worms are the major food items for *Chaetodon leniolatus* and it was considered as voracious feeder on the tentacles of polychaetes. *H.acuminatus* fed mostly on dinoflagellates, copepods and sand grains. However, *C. octofasciatus* and *C. plebius* fed mainly on corals and were found to be obligative corallivores.

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MECOS 2 |MFMP 10

Observations on foetuses of the pelagic thresher shark, *Alopias pelagicus* from the Bay of Bengal off southeast coast of India indicate smaller size at birth

Shoba Joe Kizhakudan, Muktha Menon, Joe K. Kizhakudan,
K.S.S.M. Yousuf*, K. S. Guptha and M. Shanthi
Central Marine Fisheries Research Institute, Madras Research Centre, 75, Santhome High Road,
Chennai 600 028, Tamil Nadu, India. Email: baleen@gmail.com

A female pregnant pelagic thresher shark *Alopias pelagicus* was caught in a gill net operated on 01.07.2013 in the Bay of Bengal at 200 m depth, 50 km off Kovalam (12°26.45'N lat and 80°39.50'E) on the south east coast of India. The shark was approximately 250 cm in total length and weighed 60 kg. Two near-term female foetuses (Fig.1) and ovary with developing eggs (Fig.2) were retrieved from the shark. Both foetuses were completely developed, morphologically and anatomically.
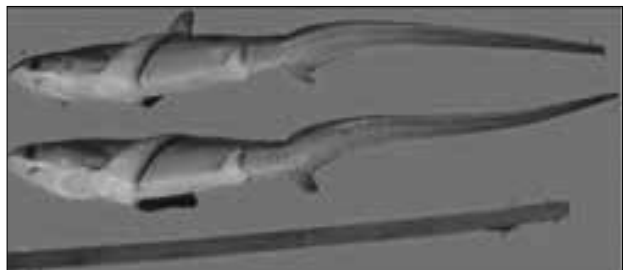
Fig.1. Near-term foetuses of *Alopias pelagicus* from Bay of Bengal off south-east coast of India

The foetuses measured 103 cm and 104 cm in total length and 1.5 kg each in weight. The right and left liver lobes measured 60 mm and 50 mm respectively in both the foetuses. Liver weights recorded were 5.1 and 5.4 g. The ovary with egg mass weighed 1.95 kg and contained unfertilized eggs of different sizes ranging

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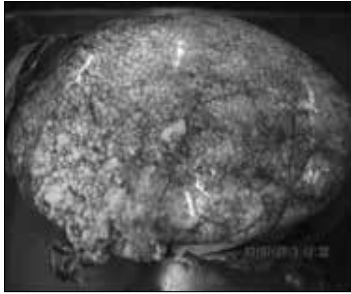
Fig. 2 Ovary with eggs

from 0.2 to 0.8 cm in diameter and 0.01 to 0.16 g in weight. The number of eggs contained in the ovary was estimated to be 22058. The yolk laden eggs formed the food of the pups and the stomachs of both the foetuses were found to be filled with a creamy fluid.

Pelagic threshers are known to be ovoviviparous with litter size of 2 (one foetus per uterus). The length at birth of pelagic thresher from the northwest Pacific has been reported to be in the range of 150 to 160 cm with a weight of 5 kg. The largest known foetus was 158 cm long and the age of a specimen of length 190 cm has been reported as one year. While the foetuses examined in the present study were comparatively smaller than the sizes described earlier, fully developed morphological and anatomical features, including the bilobed liver, suggested that they were probably approaching full term. Two young free living specimens of the pelagic thresher collected at Visakhapatnam on the northeast coast of India in June 2011 were a male and a female measuring 94 and 82.9 cm in total length.

The unusually large size of the foetus is peculiar to thresher sharks and length of the largest known foetus was found to be 43% of the length of the adult female. In the present observation, the lengths of the foetuses were 41.2 and 41.6% of the length of the adult. Each uterus was completely packed with a foetus (the tail being folded back on itself) with no free space. A foetus-adult length ratio above 40% is possibly close to a threshold carrying capacity of a female shark, increasing the likelihood of the foetuses being near-term.

While the length at maturity (L_{m50}) of *A. pelagicus* from the northwest Pacific is reported to be 287 cm, the pregnant shark in the present study was 250 cm long, which is about 87% of the estimated L_{m50}. The smaller size of the adult further justifies the possibility of smaller size at birth of the pelagic thresher in Indian waters.

Thresher sharks are not targeted by commercial fisheries in their distribution range in India. They however occur as by-catch of gillnet and hook and line operations that target scombroids. Thresher sharks are a poorly studied group, with practically no information on their biology and reproduction from Indian waters. Low resilience due to slow growth rate and low fecundity has made this species vulnerable to exploitation. The annual rate of the global population increase has been estimated to be as low as 2- 3% and IUCN has listed this species as "Vulnerable". The smaller sizes of maturity and birth indicated from the present observation are a cause for worry since they also imply longevity. Smaller size at birth also suggests increased vulnerability to predators at an early stage.

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Size at first maturity and fecundity of some commercially important finfishes from north Tamil Nadu, southeast coast of India

Shoba Joe Kizhakudan, Kotha Suresh Gupta*, Shanthi Manickam, Shiak Mohamad Yousuf, Joe K. Kizhakudan and P.U. Zacharia
Central Marine Fisheries Research Institute, Madras Research Centre, 75, Santhome High Road, Chennai 600 028, Tamil Nadu, India. Email: gupthwizard@gmail.com

Trawl fishery along north Tamil Nadu coast is supported by many commercially important species. Of late, overexploitation of many marine resources has become a matter of serious concern for sustainable fishery along this coast. Spawning stock of many commercially important fish resources are vulnerable to overfishing and have witnessed decline due to intense fishing pressure by trawlers and gillnetters in this region. Consequently, recruitment which determines the size of many fish population is adversely affected. As a measure towards formulating management strategies for conserving spawning stock, and in the context of growing annual fishing pressure every year, fecundity estimation becomes essential to ascertain the breeding frequency and reproductive potential of fishes.

Commercial mechanized fishing along north Tamil Nadu coast is mainly carried out by trawl boats and gill netters operating from Chennai. During 2011-2013, the average annual contribution by trawl and gill was 27,055 t and 1,521.7 t, respectively. About 56.5% of the total fish catch landed in Chennai during this period comprised of pelagic finfishes while demersal finfishes constituted 28.9%. In the present study, the fecundity of three pelagic and one demersal species of finfishes were estimated – the ribbonfish *Trichiurus lepturus* (23.5% of the pelagics landed), the Indian mackerel *Rastrelliger kanagurta,* (9%), the Indian oil sardine *Sardinella longiceps* (2.2%) and the Japanese threadfin bream *Nemipterus japonicus* (44% of the demersals landed).

Samples were collected from the commercial fish landings at Kasimedu fishing harbor in Chennai and brought to the laboratory in fresh condition. Samples were dissected and maturity stages of females were assessed based on size, colour pattern, distribution of blood vessels and visibility of ova. Size at first maturity was estimated by fitting a logistic equation to percentage distribution of mature individuals across length groups. Ripe gonads with fully developed ova were considered for fecundity estimation. Relationship between fecundity and fish length, fish weight and gonad weight were estimated.

Estimated fecundity for *R. kanagurta* ranged from 15,336 to 69,120 in the size range of 187-263 mm total length (TL) and 187-263 gm weight. In *T. lepturus*, the number of ova estimated was between 2,750 and 2,20,569 in the size range of 525-775 mm TL and 120-475 gm. Fecundity estimated for *S. longiceps* ranged between 12,300 to 38,988 in the size range of 172-201 mm TL and 44-82 g weight. The number of ova in *N. japonicus* ranged from 4,282 to 52,080 in the size range of 140-223 mm TL and 37-151 g weight.

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Length at first maturity was estimated to be 209.7 mm for *R. kanagurta*, 172.4 mm for *S. longiceps*, 618.8 mm for *T. lepturus* and 145.9 for *N. japonicus*. Based on length at first maturity estimated for all four species, length groups in the collected samples were categorized as juveniles, sub-adult, maturing, mature virgins and adults. Adults were predominant in the samples of *S.longiceps*, *N. japonicus*, *T. lepturus*. Sub adults and maturing individuals were found to be predominant in *R. kanagurta* collections. Dominance of these size groups in the catches on a continuous basis could be detrimental to *R. kanagurta* stocks in the region since the individuals are deprived of the chance to breed at least once, and the spawning stock biomass will diminish.

MECOS 2 |MFMP 12

Diet composition of the shrimp scad, *Alepes djedaba* (Forsskal, 1775) off Cochin

Sajana, N.* and S. Bijoy Nandan
Department of Marine Biology, Microbiology and Biochemistry, Cochin University of Science and Technology, Lake side Campus, Kochi 682 016, Kerala, India. Email: sajanasidheeq@gmail.com

Carangids are highly sought after pelagic fishes inhabiting all tropical and subtropical marine waters of the world. The shrimp scad, *Alepes djedaba* is a large species of scad representing major carangid fishery along the Indian coast. Even though the species formed promising fishery resource, few studies have been conducted to understand its food preferences. Food is one of the important factors regulating or influencing the growth, fecundity, migration and abundance of fish stocks. By identifying the favourable feeding grounds and feeding habits of commercially important fishes, appropriate fishing strategies and techniques can be designed. Hence this study is focussed to describe the diet composition and feeding intensity of *A. djedaba* off the coast of Cochin.

The samples were collected at weekly intervals from landing centres during January to December 2012. A total of 352 fishes were collected and dissected out soon after their collection; noted the distension of the stomach and preserved in 4% formalin for further evaluation. The stomachs were graded as gorged, full, ¾ full, ½ full, ¼ full, trace and empty based on degree of distension. The volume of the stomach contents were analyzed by displacement method. Percentage frequency of occurrence (Oi), based on the number of stomachs in which a food item was found, expressed as the percentage of total number of non-empty stomachs; and the percentage volumetric composition (Vi) *i.e.*, the volume of each prey item, expressed as the percentage of total volume of stomach contents in a sample. Index of preponderance was calculated following the methods of Natarajan and Jhingran (1961). Gastro Somatic Index (GSI) and Relative Length of Gut (RLG) were calculated separately for both sexes.

Though different food items were found in the stomach content of *A. djedaba*, the diet principally composed of fishes (*Stolephorus* spp. and *Leiognathus* spp.)

with a high preponderance value of 93.65 followed by digested matter (5.83). Prawn and prawn larvae were found occasionally with a preponderance value of 0.45 and 0.02 respectively. Ostracodes also contributed to the diet in negligible quantities during post monsoon season. Low feeding intensity was observed during all the months. The highest percentages of full and gorged stomachs were reported during pre-monsoon season while it was low during monsoon season. The GSI values ranged from 0.01 to 0.04 for males and 0.02 to 0.06 for females. The RLG values ranged between 0.15 to 0.19 for males and 0.12 to 0.18 for females respectively. There was no significant variation in the RLG values for different length classes and ranged between 0.15 to 0.18.

MECOS 2 | MFMP 13

A prelimnary study on the fecundity, sex ratio and length at first maturity of striped goat fish *Upeneus vittatus* (Forskal) from the Gulf of Mannar region, south east coast of India

Lakshmikanth, A.R*, M. Anand and G. Jayanthi
Madurai Kamaraj University, Madurai 625 021, Tamilnadu, India. Email: kanthmicro@gmail.com

The goat fishes were considered as ecosystem engineers and fishery indicators. The data on the biology of these fishes is very important to assess the health of the ecosystem. The present study was conducted to collect the baseline information of the fecundity, sex ratio and length at first maturity of striped goat fish *Upeneus vittatus* from Gulf of Mannar. Samples were collected from landing centers by standard methods from April 2012 to March 2013. The total length of the male fish ranged from 11.4 cm to 17.3 cm and female fish ranged from 10.4 cm to 17.5 cm. Females were found to be an asynchronous ovary pattern with an ovum size ranging from 82 to 506 μm. Based on the monthly values of gonadosomatic index and maturity stages, peak spawning was attributed between April and May. A linear relationship of fecundity with length, body weight and fecundity - ovary weight was estimated. Females were abundant at lengths greater than 14cm TL and the overall female: male ratio was 1:0.70. Length at 50% maturity was 12.9 and 12.3 cm for females and males respectively.

Morphology, meristic, otolith and osteology study of some goatfishes of the Family Mullidae (Pisces, Teleostei) of India

Karankumar K. Ramteke*, Asha T. Landge, S. K. Chakraborty, Ashok Kumar Jaiswar and Geetanjali Deshmukhe
Central Institute of Fisheries Technology, Kochi 682 029, Kerala, India. Email: kkramteke@gmail.com

A comparative evaluation between different goatfishes shows proportion of body depth to standard length of individual varied in the range of 11-39 %; maximum (34-39 %) was in *U. guttatus* and minimum (11-26 %) in *U. moluccensis*. Meristic characters such as number of anal fin rays, pectoral soft rays, gill rakers present on the lower arch, spine present in the first dorsal fin were constant i.e. 8 for all species except in *Upeneus guttatus* where it was 7. Gill rakers present on lower limb of first arch was highest in *U. sulphureus, U. moluccensis, Parupeneus indicus* (18-22). The lowest number was in *U. sundaicus* (13-15) followed by *U. tragula* (14-16). Highest number of lateral line scale was observed in *U. taeniopterus* (36-38) and lowest in *U. guttatus* (28-30). Discriminant function analysis for ten morphometric characters give misclassification of 0% for *P. indicus, U. guttatus, U. sulphereus, U. sundaicus, U. tragula, U. vittatus* and for 3% for *U. moluccensis,* 6% for *U. taeniopterus.* Number of lateral line scale present was highest in *U. taeniopterus* (36-38) and lowest number observed in *U. guttatus* (28-30). Otolith morphology study shows that wedge shape in *Upeneus guttatus* and *Parupeneus indicus,* oval in *U. sulphureus,* elliptic to truncate anteriorly in *U. vittatus,* fusiform, serrated margins in *U. moluccensis,* elliptic to truncate anteriorly for *U. sundaicus* and *U. taeniopterus,* for *U. tragula* rostrum short, slightly flattened, antirostrum poorly defined. In *Upeneusmoluccensis* parietal crest poorly developed. In *Upeneus tragula, U. moluccensis,* Pterosphenoid is not direct contact with lateral ethmoid, but joins the basisspenoid in *U. vittatus* and *U. guttatus.*

Ageing of paralarvae, juvenile and adults of purple-back flying squid, *Sthenoteuthis oualaniensis* (Lesson, 1830) based on statolith microstructure

Mohamed, K. S., K. K. Sajikumar, Geetha Sasikumar*, K. P. Said Koya and M. Ragesh
Central Marine Fisheries Research Institute, Kochi, Kochi 682 018, Kerala, India Email: gs.pallath@gmail.com

The methodology for ageing of cephalopods using growth increments in hard

structures was applied on squid species along Indian waters. In squids, the growth increments occur in hard-parts such as the squid beak, radula, gladius and statolith. The interpretation of statolith increments has been proved as the most promising method for ageing squids.In this study the age and growth of purple-back flying squid, *Sthenoteuthis (=Symplectoteuthis) oualaniensis* (Lesson, 1830), (ommastrephids) were examined by statolith microstructure and morphological measurements. The statoliths are calcareous structures located in the equilibrium organs of cephalopods, responsible for detection of linear and angular acceleration.

Exploratory jigging surveys undertaken along the eastern Arabian Sea by Central Marine Fisheries Research Institute identified spawning grounds of the purple back oceanic squid *Sthenoteuthis oualaniensis*. The study conducted as part of an NAIP, collected oceanic squids in Lakshadweep waters between 10º00 N 71º59 E and 10º14 N 73º44 E (between Agatti and Kalpeni Islands) during October. Dense aggregations (~130,000 numbers/km2) of oceanic squid paralarvae and juveniles with dorsal mantle lengths (DML) ranging from 5 to 11 mm size were collected from the water surface during 1900-0001h and 0300-0500h. Adult squids were collected in squid jigs, paralarvae and juveniles were collected by using scoop net (2mm mesh size). The squids were attracted to the powerful lights (1.5 KW x 18 metal halide lights) on board the vessel at station depths ranged from 700 to 1500 m. In the laboratory, statoliths were extracted by surgically dissecting the severed squid head in the frontal plane manually. The tissue fragments attached to the statoliths after dissection were removed prior to mounting for proper observation. They were mounted on glass slides using thermoplastic glue for grinding. After drying, the statoliths of juveniles and adults were ground using lapping films and observed under binocular microscope continuously for completely grinding the opaque area. In paralarvae, the statoliths were translucent, and therefore they were examine without grinding. Growth rings were counted using the binocular microscope by changing the focal plane under higher magnifications.

The age in days for the purple-back flying squid paralarvae of DML 5.7-8.8 mm ranged from 18-32 days. In juveniles of DML ranging from 9.2 to 11.01 mm the age was 22-35 days and adults of 115-123 mm DML were aged as 63-72 days. The growth index (GI) was 0.326±0.062 mm/day in paralarvae; 0.351±0.05 mm/day in juvenile and 1.773±0.152 mm/day in adults. The growth index of female squids based on statoliths was extrapolated for arriving at estimates of monthly dorsal mantle lengths (Fig. 1). The results were then compared with the monthly mantle length projections based on length-based growth estimation methods.

Projected monthly mantle lengths

	30	60	90	120	150	180
Statolith increments	5.3	10.6	16.0	21.3	26.6	31.9
Length based estimation	19.2	22.5	25.2	27.4	29.2	30.7
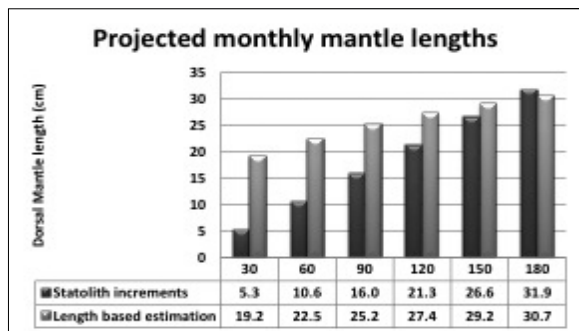
Fig. 1.Projected monthly mantle lengths (cm) based on adult growth index in female *S. oualaniensis*

Histological observations of testis of the squid *Sepioteuthis lessoniana* Lesson 1830 from Palk Bay, Mandapam, India

Venkatesan, V.* and S. Rajagopal
Central Marine Fisheries Research Institute, Kochi 682 018, Kerala, India.
Email: venkatcmfri@yahoo.co.in

Sepioteuthis lessoniana (Lesson,1830), commonly known as bigfin squid or oval squid is an important target species in many fisheries around the world. *S. lessoniana* is an Indo-Pacific neritic species occurring from the surface down to at least 100 m depth. In India, squids are caught mainly as by catch in trawl nets used for shrimp/fish trawling, shore seines, boat seines, hook and line and stake nets. It represents the most common species of coastal pelagic squids found along the Palk Bay and Gulf of Mannar of India. Male squids with testes in different stages of development were collected from Mandapam landing centre during the fishing season. The objective of the present study is to describe male reproductive system and the phases of gonad development in *S. lessoniana*. The different stages of gametogenic development were examined microscopically. Gonad development stages were matched in accordance with our macroscopic and microscopic observations. Based on histological observations, male gonads were classified into four main stages of development. Squids examined also were divided into four main groups according to the degree of development of spermatozoa within seminiferous tubules.
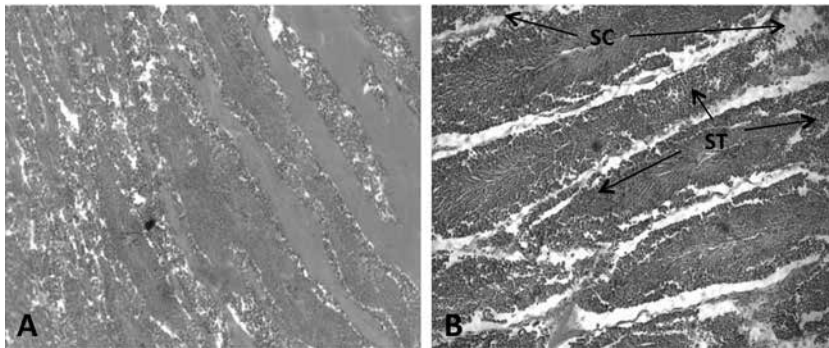
Fig. 1. A. Stage I - Testis of immature male showing tubules in early stages of development. B. Longitudinal section through an individual seminiferous tubule of a stage II animal. Secondary spermatocytes (SC) and spermatids (ST).

Reproductive indicators and ovarian development in the squid *Sepioteuthis lessoniana* Lesson,1830 from Palk Bay, Mandapam, India

Venkatesan, V.* and S. Rajagopal
Central Marine Fisheries Research Institute, Kochi 682 018, Kerala, India
Email: venkatcmfri@yahoo.co.in

Sepioteuthis lessoniana (Lesson,1830), is one of the most widely distributed loliginid squid of the Indo-West Pacific region. It is a large coastal squid known to occur commonly in coastal environments on sea grass beds, coral reef and sandy bottoms of Palk Bay and Gulf of Mannar region. *S. lessoniana* accounts for around 7 % of cephalopod landings along east coast of India. At Mandapam, *S. lessoniana* contributes 11 % of total cephalopod landings. It is exported to niche markets like Japan, Europe and China. Gonadosomatic index, monthly progression of maturity stages, histological analysis of ovarian development and description of structure of female reproductive system was carried out in *S. lessoniana* collected from the shrimp trawlers operated along Mandapam coastal areas. Based on the monthly progression of maturity stages, larger numbers of mature females were identified in January and February. This result coincided with the gonadosomatic index. The different stages of gametogenic development were examined microscopically. Oocyte growth follows the general pattern observed in other squids. According to the histological analysis, six sub-phases of oocyte development were identified, and these are similar to those described for other species. Different phases of oocyte growth such as oogonia, primary oogonia, secondary oogonia, maturing phases of growth, postovulatory follicles and atresia were detected. During maturation of oocyte, follicle cells transforms from cuboidal to columnar. Oocyte size among types showed significant differences.
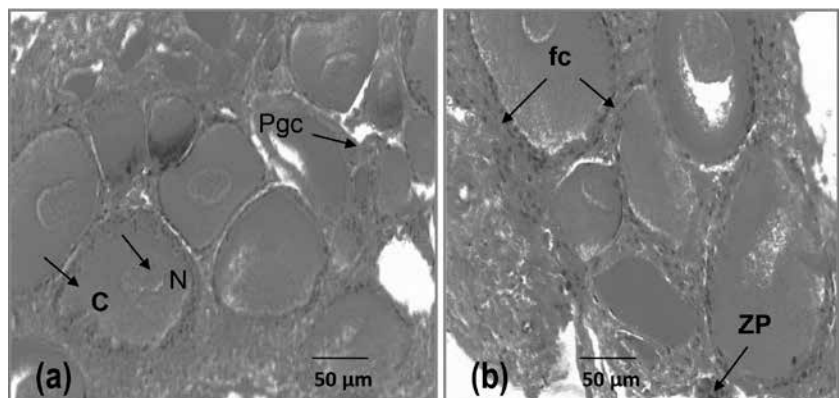
Fig. 1. a. Stage I - Ovary of immature female showing oocytes in early stages of development. Primordial germ cells (oogonia) pgc can also be seen. (b). Oocytes and follicle cell proliferation. Attachment of follicle cells in stage II. Cytoplasm (C), Nucleus (N), Follicle cells (fc), Zone of follicle cell proliferation (ZP).

Trends in penaeid prawn landings by sona boats at Visakhapatnam fishing harbour during 2001-2010

Maheswarudu, G.*, Miriam Paul, E. Dhanwanthari, J. B. Varma, C. K. Sajeev and S. Satya Rao
Central Marine Fisheries Research Institute, Visakhapatnam Regional Centre, Visakhapatnam 530 003, Andhra Pradesh, India. Email: maheswarudu@yahoo.com

Sona boats (13-15m OAL) which are worthy to conduct voyage fishing for 10-20 days exploit resources up to a depth of 100 m, mostly in the northern part of Bay Bengal upto sand heads. Annual fishing effort of sona boats ranged from 4,77,710 hrs to 16,31,507 hrs with an average of 10,15, 230 hrs. Annual penaeid prawn catch varied from 1,409 t to 7,496 t with an average 4,892 t, and CPH ranged from 2.95 kg to 7.98 kg with an average of 4.81 kg. Penaeid prawn contribution to annual total fish landings ranged from 9.32 % to 29.52 % with an average at 17.15%. Increasing trends were observed in both fishing effort as well as penaeid prawn catch over the period. Penaeid prawn catch has supported by 14 genera/ species of which *Metapenaeus monoceros* dominated followed by *M. dobsoni*. Mean annual species composition and CPH for each species were computed for two spells, one for 2001-2005 and the other for 2006-20010. The CPH for all penaeid prawns has decreased by 11.5% from spell -1 to spell-2. CPH for small sized prawns has declined whereas it has increased for commercial species (Table, 1). Expected catch for each year was estimated by using Schaefer production model (CEDA; $r^2 = 0.72$) and observed that exploitation was under expected state for three years, optimum state for three years, and above expected state for four years. In terms of total fish landings: exploitation was under expected state for two years, at optimum land for six years and above expected land for two years. By considering exploitation state of both penaeid prawn catch and total fish landings it is advised that restriction of fishing effort at present level is necessary to ensure exploitation of both resources at sustainable level.
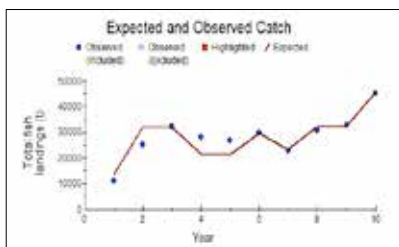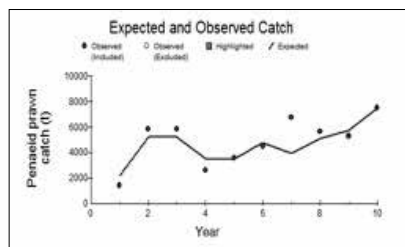
Table 1. Species-wise comparison of mean annual catch, composition and catch/hour of sona boats between two spells

| SPECIES | 2001-2005 | | | 2006-2010 | | | |
	Catch (t)	%	CPH (kg)	Catch (t)	%	CPH (kg)	(+)/(-) in CPH
Metapenaeus monoceros	570.5	10.31	0.68	2069.5	30.29	1.76	160.1
M. dobsoni	393.4	7.11	0.47	746.7	10.93	0.64	36.1
M. brevicornis	0.0	0.00	0.00	72.0	1.05	0.00	0.0
M. affinis	0.0	0.00	0.00	225.5	3.30	0.19	0.0
Metapenaeopsis sp.	529.6	9.57	0.63	619.4	9.07	0.53	-16.2
Penaeus indicus	216.0	3.90	0.26	333.4	4.88	0.28	10.7
P. monodon	82.4	1.49	0.10	235.6	3.45	0.20	105.0
P. merguiensis	0.0	0.00	0.00	9.0	0.13	0.01	0.0
P. japonicus	0.0	0.00	0.00	53.6	0.78	0.05	0.0
P. semisulctus	36.3	0.66	0.04	102.4	1.50	0.09	102.6
Solenocera spp.	326.7	5.90	0.39	1141.5	16.71	0.97	150.5
Parapenaeopsis sp.	357.2	6.46	0.42	349.9	5.12	0.30	-29.8
Trachypenaeus spp.	114.9	2.08	0.01	97.5	1.43	0.08	508.3
Parapenaeus sp.	28.3	0.51	0.03	90.2	1.32	0.08	128.2
Miscellaneous	279.4	5.05	0.33	56.5	0.83	0.05	-85.5
Dry prawns (Converted into wet wt.)	2598.5	46.96	3.08	629.8	9.22	0.54	-82.6
Total	5533.1	100.00	6.57	6832.5	100.00	5.81	-11.5

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Fishery, biology and population dynamics of the deepwater Caridean shrimp, *Heterocarpus gibbosus* (Bate, 1888) along the southwest coast of India

Rekha Devi Chakraborty*, G. Maheswarudu, J. Jayasankar and C. K. Sajeev
Central Marine Fisheries Research Institute, Kochi 682 018, Kerala, India. Email: rekhadevi76@yahoo.com

Heterocarpus gibbosus Bate, 1888 forms a major species (18%) contributing to the deepsea shrimp fishery with an average annual estimated landings of 1053 t and catch per unit effort (CPUE) of 2.3 Kg/h off the Sakthikulangara fishing harbour, southern coast of Kerala, during 2006-2011 (Fig.1). The R function nls (non-linear regression model) was used for estimating the length-weight (CL & Wt) relationship parameters (Male: a=0.001461, b=2.57; Female: a=0.00072, b=2.82) revealed the isometric growth in both male and female (p<0.05). Sex ratio was in favour of females (1:1.02) which is non significant (chi-square=0.1265, P>0.05). Annual mean size and modes ranged from 101-105 & 93-108 mm in males and 106 - 107 and 98 -108 mm in females, respectively. Growth parameters estimated by von Bertalanffy's growth equation were: L_∞ = 152 mm, K = 0.6 for males and

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L$_\infty$ = 155 mm, K= 0.4 for females. L$_{m50}$ was calculated as 93 mm using the non-linear model (WinBUGS 3.0.3). The length at recruitment (L$_r$) and length at 50% capture was 56, 96 mm (males) and 61, 144 mm (females), which corresponds to an age (t$_c$ at L$_r$) of 11 months and 15 months, respectively. Instantaneous total mortality (Z), natural mortality (M), fishing mortality (F) were in the order of 3.26, 0.77, 2.49 & 2.40, 0.59, 1.81 for males and females, respectively. Exploitation ratio was found to be same in males and females (0.76). The exploitation ratio for *H. gibbosus* was found to be lower than the E$_{max}$ and LCOHOR analysis revealed the spawning stock biomass was 50% of the standing stock biomass which indicates the exploitation of the resource at sustainable level.

MECOS 2 |MFMP 20

Morphometrics and length-weight relationships of the Herring Bow crab *Varuna litterata* Fabricius from Cochin backwaters, a south Indian estuary

Deepthi Gopi Nair, P. Lakshmi Devi, Aneykutty Joseph* and Alphi Korath
School of Marine Sciences, Cochin University of Science and Technology, Kochi 682 016, Kerala, India.
Email: aneykuttyj@yahoo.co.in

The present study deals with the interrelationships of various morphometric characters, viz., carapace width and length, chelar propodus length and depth in males, as well as carapace width and length, abdominal length and width in females of the herring bow crab *Varuna litterata* collected for a period of two years from Cochin backwaters, a south Indian estuary. The carapace width/length - weight relationship was established using the allometric growth equation of von Bertalanffy in both the sexes. The allometric relationships between these morphometric characters suggest that most relationships are positive and highly significant. The 'b' values of the carapace width - weight and carapace length-weight relationship of males are 3.0211 and 3.3105 respectively indicating an isometric pattern of growth whereas the 'b' values of carapace width - weight and carapace length- weight relationship of females are 2.2990 and 2.5084 respectively indicating allometric pattern of growth. In the present study, sex ratio of *V. litterata* was analysed both season-wise and size-wise using Chi-square analysis. The study showed an overall dominance of females compared to males when the pooled data is considered. The entire Chi-square analysis showed that sex ratios more or less followed the theoretical ratio of 1:1.

Validation of age and growth of Yellowfin tuna (*Thunnus albacares*) using hard parts

Abdussamad, E. M.*, P. Shameer, T. B. Retheesh and D. Prakasan
Central Marine Fisheries Research Institute, Kochi 682 018, Kerala, India. Email: emasamadg@gmail.com

Age and growth of yellowfin tuna was estimated using length frequency data. However, the present estimates and similar earlier estimates vary widely, casting doubts on the reliability of these estimates for further analysis. Since accurate information on age of fish being an important pre-requisite for extracting precise information on growth, mortality, recruitment and other fundamental population parameters of fishes for stock assessment, the growth inscriptions on the hard parts like otoliths, scales and dorsal spines were used to validate the above estimates. Among the hard parts used, inscriptions on otoliths alone shows direct correlation with age of the fish and so used for validation of age estimate. Conventional method of age analysis using length frequency analysis shows that yellowfin tuna attains 50 cm FL during first year. Otolith inscriptions indicates that the species grow much faster and attain 65cm FL during first year.

Method	1st year	2nd year	3rd year	4th year
Length frequency (modal progression)	50.2	88.3	117.3	139.5
Otolith inscription (growth rings)	65	108	131	148

A comprehensive database on the marine fisheries of Odisha coast

Reeta Jayasankar and Sukadev Bar
Central Marine Fisheries Research Institute, Puri Field Centre, Puri 752 002, Odisha, India.

Odisha has a coastline of 480 km transgressing six coastal districts, a huge mangrove forest of Bhitakaniaka, largest brackish water lake of Chilka and supplemented rivers like Mahanadi, Rusikulya, Daya, Devi, Subarnarekha, Budhabalanga, Brahmani, Baitarani, Hansua, Kadua, Kushabhadra, and Bahuda directly or indirectly connected to the Bay of Bengal with their delta and estuarine ecosystems making each with a variety of ecological niches and habitats. It is one of the most dynamic coastal environments in India due to its location and physical factors. This paper presents detailed insight of the coastal area, the biotic and the

abiotic resources, its climate and vulnerability, marine fisheries status, endangered species like seaturtle and Irrawaddy dolphin, coastal villages and the communities, their livelihood and the coastal biodiversity. The coast does not have many harbors, fish landing centers, processing units, post harvest and marketing facilities making the fisherfolk communities to depend on neighboring states. Many advanced technologies like marine finfish and bivalve farming, processing, hatcheries for shrimps, crabs and fish, fish feed, utilization of the waste, coastal pollution and cage farming have not yet reached this state.There is ample scope for development of the marine sector and improvement in the livelihood conditions of the coastal fisherfolk.

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Biology and population parameters of Commerson's anchovy *Stolephorus commersonnii* (Lacepede) along Kerala coast

Preetha G. Nair*, V. Kripa, Shoji Joseph and V. N. Pillai
Central Marine Fisheries Research Institute, Kochi 682 018, Kerala, India. Email: preethagnair@yahoo.in

Anchovies form 6.3% of the pelagic catch in Kerala and these form a major source of income for the traditional fishermen in Kerala. The major species available throughout the coast are *Encrasicholina devisi, Stolephorus bataviensis, Encrasicholina punctifer, Stolephorus commersonii, Stolephorus indicus, Stolephorus baganensis* and *Stolephorus macrops*. Of these *S. commersonii* is the second major species (27%) with a size range 7.5 cm to 15.5 cm. Growth and maturity of the different species of anchovies have been studied by different authors. But there exists no study on the fishery and biology of *S. commersonnii*. The present study is the first report on the growth and maturity of *S. commersonnii* along the Kerala coast.

Fresh unsorted weekly samples of *S. commersonnii* caught by ring seines and purse seines were collected from different fish landing centres of Kochi during 2010-2011. A total of 795 number of anchovies were used for the present study. Total length was taken from the tip of the snout to the tip of the caudal fin nearest to 1.0 mm and weight was taken nearest to 0.1 g. Gonadal stages I and II were considered as juveniles and from III to VI as matured fish. The stages of maturity classification of male and female gonad were as given by Antony Raja (1971).

The pooled length data for each month were sorted and grouped in to 1 mm class intervals and the time series observations of 455 male fishes and 340 female fishes were used for the analysis. The length frequency data was analysed by using by ICLARM's FiSAT software to estimate the growth parameters L_∞ and K. The length at age (t_0) was estimated from the empirical equation $t_0 = -(\exp(-0.392-0.275 \times \ln(L_\infty)-1.038 \times K))$.Following Pauly (1983), life span was calculated using the parameters of the von Bertalanffy growth function by the formula, $t_{max} = 3/K$. Total mortality (Z) and exploitation rate (E) were estimated from the catch curve.

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Natural mortality (M) was calculated by empirical relationship of Pauly (1980) and fishing mortality (F) was calculated from total mortality (Z) and natural mortality (M) by length converted cohort analysis. Recruitment pattern was obtained by the back projecting in to the time axis by means of a single set of growth parameters of a set of length frequency data which are analysed using ELEFAN programme. The probability of capture by length was calculated by the ratio between the points of the extrapolated descending arm of the length-converted catch curve using the FiSAT software.Maturity curves were drawn to the scatter plots to estimate the length at which 50% of fish mature.

The growth parameters obtained from Von Bertalanffy growth equation are Length infinity (L_∞)= 15.4 cm, K = 0.98 year -1 and t_0 = -0.1152 which shows that the species attain a maximum length of 15.4 cm (Total mortality (Z), Natural mortality (M) and fishing mortality were estimated as 2.78, 2.12 and 0.64 respectively. The exploitation rate 0.23 indicates that the species is not exposed to higher fishing pressure. t max 3.061 year shows that the lifespan is around 3 years. The length frequency histogram for the probability of capture shows that the length range of the anchovy in the fishery is between 7 to 12 cm. It was observed that the recruitment period is extended with peak during May to August with two small subsequent recruitments in October –November and February- March (Fig.1).

The length at first maturity of male and female was estimated as 7.1 and 7.2 mm respectively (Fig.2 and 3) which is similar to the values obtained for *S.bataviensis* and *S.devisi* along Karnataka coast (Rao,1988).
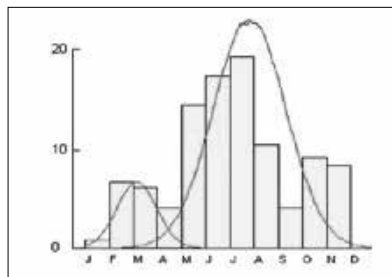
Fig.1.Recruitment pattern of *S.commersonii* during 2010-2011
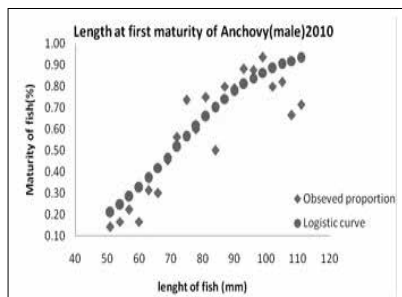
Fig.2. Length at first maturity (Lm) of male *S.commersonii* during 2010
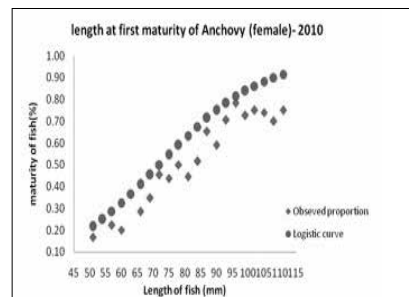
Fig.2. Length at first maturity (Lm) of male *S.commersonii* during 2010

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Temporal variation in the diet components of Indian oil sardine, *Sardinella longiceps* off Mumbai waters

Anulekshmi, C, S. Ramkumar*, G. B. Purushottama, K. Syamala, S. D. Kamble, Sujitha Thomas, P. U. Zacharia, V. D. Deshmukh and Veerendra Veer Singh

Central Marine Fisheries Research Institute, Mumbai Research Centre, Versova, Mumbai   400 061, Maharashtra, India. Email: ramfrm@gmail.com

The temporal variation in the diet components of Indian oil sardine, *Sardinella longiceps* caught by purse seiners and gill netters from off Mumbai waters during 2011-2013 was studied. Feeding intensity varies with size of the fish and the seasons. The index of preponderance (IP) shows that the fish feeds mainly on copepods (38.42%) followed by *Coscinodiscus* sp. (26.36%) and *Skeletonema* sp. (17.6%). Gastrosomatic index (GaSI) shows that the active feeding of male and females were taken place during the month of April (1.77 and 1.8 respectively) followed by November (1.68 and 1.77 respectively). Maximum feeding intensity was observed at a size of 151-155 mm TL (22.53%) and 156-160 mm TL (19%). Diet similarity was observed during pre-monsoon and post-monsoon season with 65%. Copepod was the dominant prey item during pre-monsoon and monsoon with 36% and 68 % I_p respectively. During post monsoon *Coscinodiscus* sp. and Copepods were with nearly similar % I_p. The feeding intensity is high during post-monsoon (54%) followed by pre-monsoon (35%) and monsoon (11%). Low feeding intensity was observed during monsoon period which is coinciding with the breeding season of the fish.

Rapid stock classification of marine fish stocks along Andhra Pradesh

Shubhadeep Ghosh*, M. Muktha, M. V. Hanumantha Rao and Pralaya Ranjan Behera

Central Marine Fisheries Research Institute, Vishakapatanam Regional Centre, Visakhapatnam 530 003, Andhra Pradesh, India. Email: subhadeep_1977@yahoo.com

The status of fish stocks along Andhra Pradesh coast, both before (1950-1980) and after (1981-2012) the introduction of voyage fishing by large mechanized trawlers was ascertained in the present study. Decadal growth rate was positive for all the decades from 1960-2009, with highest growth rates observed in decades coinciding with maximum fishing innovations. During 1978-1980, 8% of the species/groups were abundant, 44% were less abundant, 32% were slow declining,

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catfishes and goatfishes were rapidly declining and mullets and *Hilsa ilisha* were depleted. This was because of continuous intense exploitation in nearshore waters from 1950 to 1980. With expansion of fishing grounds and commencement of offshore fishing from 1980 onwards, the health of stocks improved. In 2010 – 2012, 50% of the species/groups were abundant, 25% were less abundant, 18.75% were slow declining, Lactarius lactarius and mullets were rapidly declining and *Hilsa ilisha* were collapsed. The collapse of *Hilsa ilisha* is because of its inability to perform spawning migrations upstream rivers. Most of the rivers in Andhra Pradesh remain dry for majority of the year and the lower stretches and estuaries become hypersaline with sea water intrusion, forming an obstacle in the migratory path of *Hilsa ilisha*. It is therefore suggested that a minimum discharge volume of freshwater from rivers to sea should be ensured for all rivers of Andhra Pradesh.

MECOS 2 |MFMP 26

On a hybrid modeling approach for studying propensity dynamics of marine fishery resources in south western EEZ of India

Jayasankar, J.*, K. G. Mini, Grinson George, T. V. Ambrose and Sindhu K. Augustine
Central Marine Fisheries Research Institute, Kochi 682 018, Kerala, India. Email:jjsankar@gmail.com

Fish population dynamics has always been fancied by fishery observers with reverence as well as contempt. The fascination towards studying the ups and downs of the natural resources in general and fish populations in particular have lead to many creative approaches, which have opened up new vistas of knowledge. The copious application of engineering and physical equilibrium models are the best examples for this. This work attempts to rework the analytical parts of such modeling approaches with specific reference to Indian Exclusive Economic Zone (EEZ). With more than 2,500 species of fishery resources reported through commercial catches, and many objective categorization of these resources put in place, the task of the modeler gets cut out. In this work an attempt is being made to analytically include major resources of economic importance found in the EEZ into habit/ habitat based groups which are listed below:

- Highly dynamic fishes with higher trophic levels
- Dynamic groups with lower trophic levels
- Near sedentary fishes and
- Non-stereotype fishes

The well known approaches like the advection-diffusion model, phyto-zoo-detritus based models and energy balancing models have been applied to relevant select five resources and their populations were simulated for the south west Region of the Indian EEZ. These simulated models were then validated with selective summary landings which include seasonal effects and corresponding derived population figures for the period 2011- 2013 obtained from. The results

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indicated presumptive loss of fitness due to model parsimony is less which is against the common perception. More factors, preys and predators, weakened the prediction performance of the models to the extent of 20%. Another notable finding of this study is the near loss of mapping between the niche models and the candidate resources. Hence an appropriate hybrid modeling approach has been proposed which proves to be better in terms of validation of simulated data. This exercise clearly indicates that the modeling of fishery resources in the Indian EEZ has to be woven around a robust platform of mosaic model blocks, with proper adjustments for "not so macro" factors which affect the niche of the resources. It also indicates that such an exercise has to be a blend of generic approaches and the proportion of admixture is fully decided by the spatio-temporal conditions prevailing in the area under focus.

MECOS 2 |MFMP 27

Present status of marine fisheries in Tamil Nadu with an assessment of the stock position of major resources

Sivadas, M.*, P. T. Sarada, I. Jagadis, A. Saravanan, Shoba Joe Kizhakudan, Margaret Muthurathinam, Indira Divipala, K. N.Saleela, R. Narayana Kumar and Grinson George
Central Marine Fisheries Research Institute,Tuticorin Research Centre, South Beach Road, Tuticorin 628 001, Tamil Nadu, India. Email: sivadasmadhav@yahoo.com.

The data for the years 2002 to 2013 from the fisheries resource assessment division of CMFRI and the biological data of dominant species collected from different centres form the database for the present study. The total production in Tamil Nadu ranged from 2.8 lakh t in 2005 to 6.89 lakh t in 2013 with an average of 4.67 lakh t during 2002 to 2013. The major contributors were mechanized trawlers (54%), outboard gill netters (OBGN) 22.4%, non-mechanized (NM) 5%, outboard hook and liners (OBHL) 3.7%, outboard ring-seiners (OBRS) 3.6% and mechanized ring-seiners (MRS) 2.7%. MRS started operating from 2009. So the period was divided into two, i.e. 2002 to 2008 and 2009 to 2013. The average landing during the former period was 3.85 lakh t. Trawlers contributed 47%, OBGN 29%, NM 9% and OBHL 4.1%.

During 2009 to 2013, the average landing shot up to 5.8 lakh t. The percentage contribution of trawlers also increased to 59% but OBHL remained same around 4%. The ring seiners contributed 11%. However, the contribution of OBGN decreased to 16% and that of NM to mere 2%. But as far as the total number of units operated, it could be seen that OBGN formed 56%, NM 20% and OBHL 8%. The percentage of trawlers was only 11 and that of ring seiners 0.5. This clearly indicates the significance of traditional fishermen in Tamil Nadu fisheries. As in the case of total landing, the number of units operated during 2002-2008 and 2009-2013 showed great variations. The percentage of the total number of effort expended during 2002-2008 was 10 for mechanized trawlers, 28 for NM, 52 for

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OBGN, & 7 for OBHL. During the latter period, the percentage of trawlers had increased to 12, OBGN to 63, OBHL to 11 in addition to the contribution of 1% by ring seiners. However the contribution of NM had decreased to 7%.

The oil sardine was the major species among pelagic forming 48% and in demersals, silverbellies dominated forming 42.7%. Among crustaceans, the penaeid prawns formed 59.9% and crabs 32.6%. In regard to the spatial landing, the area (1) comprising Nagapattinam, Tanjavore, Pudukottai and Ramanathapuam contributed an average 41% of the total landing followed by the area (2) comprising Tuticorin, Tirunelveli and Kanyakumari of 37%. The contribution from the area (3) comprising Tiruvallur, Chennai, Kanchipuram, Cuddalore and Villupuram was 22%. In area 1, the single day mechanized trawlers (MTN) was the major contributor with 49% followed by multiday trawlers (MDTN) of 24%. Thus they together formed 73% of the total landing here. In area 2 also, the major contributor was MTN forming 43%. But the contribution of MDTN was only around 3%. The other major contributors were OBGN (30%), OBHL (7%) and OBRS (5%). But in area 3, the contribution of MTN was only 12% whereas MDTN was around 20%. The percentage contribution of OBGN was 25, OBRS 6 and NM and OBBN 5 each. The area 1 landed 70% of the total oil sardine landing of Tamil Nadu. The other dominant species/groups were *Scomberomorous commerson* (57%), silverbellies (74.8%), goatfishes (55%), croakers (73%), penaeid prawn and Octopus spp (77% each), crab (82%) and cuttlefish (51.8%). The area 2 showed preponderance of lesser sardines (59.3%), white baits (56.7%), *Acanthocybium solandri* (71%), pigface bream (57%), non-peaneid prawn (97.9%) and squids (62.9%). In Area 3, the dominant species were *Euthynnus affinis* (80%) and *Katsuwonus pelamis* (47%). Spatial differences in the species composition of different resources were also noticed.

The rapid stock assessment of the 19 major resources/resource groups indicated that oil sardine and mackerel were in abundant state. The resource groups that were also found in abundant state were other sardines, whitebaits, tuna, seer fish, billfishes, rays, goatfishes, lizard fish, snappers, pigface bream, threadfin breams, silver bellies, penaeid prawn, crab and cephalopod resources. Non-penaeid was under declining state.

The predictive analysis (T&B model) of some the major pelagic resources like mackerel, skipjack tuna, kawakawa indicated that the present fishing is not affecting them adversely. At Tuticorin, the juvenile stock of prawns and crabs were overexploited by indigenous trawl net. In the case of mechanized trawlers also, the stock was slightly over exploited. In the case of estuarine gill nets and marine gill nets, the present level of fishing pressure can be continued.

Impact of trawl fishing ban on the stock renewal of some demersal resources off Mangalore coast, eastern Arabian sea

Sujitha Thomas* and A. P. Dineshbabu

Central Marine Fisheries Research Institute, Mangalore Research Centre, Hoige Bazar, Mangalore 575 001, Karnataka, India. Email:sujithacmfri@yahoo.co.in

Marine fisheries sector which contributes to national economy of the country has witnessed a phenomenal growth during the last few decades. Technological interventions in mechanized sector have made an impact on the marine fish production immensely. Contribution of mechanised sector (formed mainly of trawlers and purse seines) has dominated during last three decades. In the end of 1990s their contribution was around 50% which increased to 65 % by 2000 and to 78 % in 2012 (3.08 million t.). Since fishery resources provide food and livelihood security to millions of people living along the coast, it need to be monitored and managed to maintain harvest at sustainable level. Management measures adopted in multispecies multigear scenario in Indian waters is formulated taking into consideration the domestic situation to promote sustainable fishing practices that will not decrease the stock level, but will ensure livelihood security, resource sustainability, economic efficiency and ecosystem integrity. Seasonal fishing ban is one such tool introduced as a measure of reducing the impact of the mechanized fishing along Indian coast and assiduously followed by all maritime states. Since the seasonal fisheries ban, the fisheries sector has undergone technological and economic changes. An attempt was made to study the impact of such seasonal closures on the stock renewal of some demersal resources exploited off Mangalore coast.

Analysis was carried out on the major trawl resources viz threadfin breams (*Nemipterus japonicus* and *N. randalli*) and lizard fishes (*Saurida tumbil*) and shrimps (*Metapenaeus monoceros*). Data on catch and effort of commercial trawlers operating from Mangalore landing centre as well as length of these species were collected twice a week. The data were weighted for monthly values. The length data obtained on each observation day were raised to the day's catch and these were further raised to get monthly length composition of the catch. Length frequency analysis was carried out to understand the impact of seasonal trawl ban on the fishery related characteristics of the species. For analysis the length frequency distribution of three months before trawl ban (March-May) and post trawl ban period (Aug–Oct) were used.

In *N. japonicus*, the higher length range 165 mm to 345 mm was seen predominantly in postban period (Fig. 1) and in *N. randalli* similar domination of higher length range (125 to 245) was observed during postban period (Fig. 2). These indicate that there is a significant improvement in spawning population as a result of closure of fishing. In the case of *M. monoceros*, also the domination of

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spawning population (>118 mm) was seen during postban season period (Fig.3). High percentage of spawning population indicates that fishes got opportunity to grow beyond the length at maturity during closure of fishery and ensure the recruitment success in following years. In lizard fishes, the impact of the trawl ban in the recruitment is evident from the length frequency analysis. Very significant increase of recruitment size (105-165 mm) was observed in the species during the post ban period (Fig.4).

The analysis clearly shows that there is improvement of the spawning population of *N. japonicus*, *N. randalli* and *M. monoceros* during the postban period and in case of *Saurida tumbil* the recruitment which was estimated from three lowest length categories was high after the ban season, which indicates enhanced recruitment for a short duration after the ban period. Thus the study indicates that the trawling ban helps to retain a healthy percentage of spawning population to the species studied.
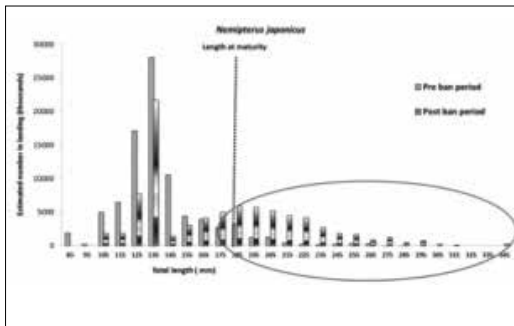
Fig 1. Comparison of length frequency of threadfin breams, *Nemipterus japonicus* prior to closure of mechanised fishing (pre-ban period) and during the start of the following trawl season (post-ban period), 2012-13.
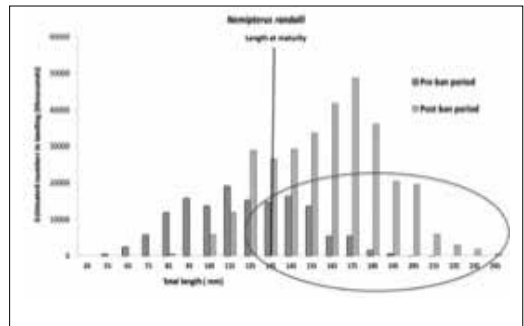
Fig 2 Comparison of length frequency of threadfin breams, *Nemipterus randalli* prior to closure of mechanised fishing (pre-ban period) and during the start of the following trawl season (post-ban period), 2012-13.
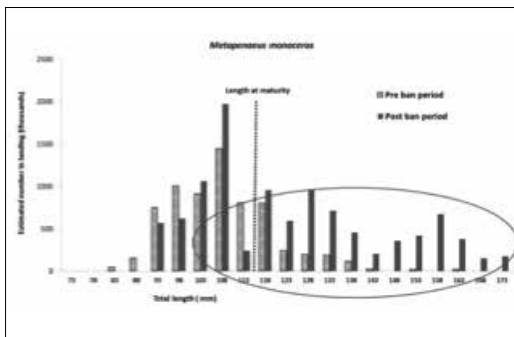
Fig 3. Comparison of length-frequency *M. monoceros* prior to closure of mechanised fishing (pre-ban period) and during the start of the following trawl season (postban period), 2012-13
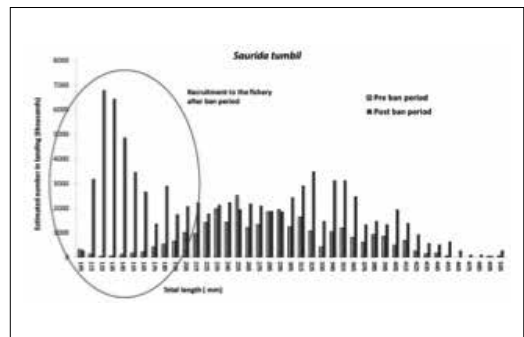
Fig 4. Result of the length frequency analysis of the landings of lizardfish, *Saurida tumbil* during 2012-13.

Studies on the deep-sea Alepocephalids of the Arabian Sea

Ganga, U.*, P. T. Jinesh, N. Beni and Sandhya Sukumaran
Central Marine Fisheries Research Institute, Kochi 682 018, Kerala, India. Email: ganga@cmfri.org.in

Alepocephalids commonly known as slickheads are truly deep-sea fishes with most of the species commonly occurring beyond 500 m depth. Based on the deep-water surveys by RIMS Investigator during 1885-1899, Alcock (1899) listed 12 species belonging to 5 genera namely *Alepocephalus, Bathytroctes, Narcetes, Platytroctes, Aulastomatomorpha, Xenodermichthys* and *Leptoderma* from Indian seas of which *Platytroctes* is now assigned separately to the family *Platytroctidae*. The collection in the course of deep-water fisheries exploratory surveys in the south eastern Arabian Sea on-board FORV *Sagar Sampada* indicated one more genus represented, namely *Talismania* to the 23 genera currently recognized in the family *Alepocephalidae*. In the *Narcetes genus,* an additional species *Narcetes lloydi* was recorded. While some reports of these species from India were found during a literature survey it was observed that no morphometric data or records kept in fish collections or museums were reported. Taxonomic data on alepocephalids which is a diverse group of deep-sea fishes where many problems with identification and nomenclature are reported is important for comparative studies. The morphometric data along with DNA barcodes of 5 species of Alepocephalids and the biology of two species *Talismania longifilis* and *Narcetes lloydii* are detailed in this study. Absolute fecundity of mature specimens of *Narcetes lloydi* measuring 55 – 57 cm in total length and weighing 1.3 – 1.7 kg each ranged from 452 - 1139 eggs with ova diameter 2.4 - 3.2 mm. Spatial abundance and distribution of the 5 species of alepocephalids as obtained through trawling data from various stations during cruises is reported. Among the catch of alepocephalids in various transects, the *Alepocephalus* spp. was the most dominant group (50-95%) followed by *Rouleina* (12 – 50%). Among species *Talismania longifilis* was more abundant in the 80 N latitude, *Rouleina attrita* in the 11˚N latitude while *Alepocephalus* spp. had a more wide distribution from 8˚ -11˚N latitudes.

Evidence supporting panmixia in cobia *Rachycentron canadum* along Indian coast using microsatellite markers

Divya, P. R, A. Gopalakrishnan, V. S. Basheer, T. Raja Swaminathan, Linu Joy*, C. Mohitha and J. K. Jena
National Bureau of Fish Genetic Resources (NBFGR) Cochin Unit, Kochi 682 018, Kerala, India.
Email: linupulickal@gmail.com

Cobia, *Rachycentron canadum* is an important species for commercial fishery, as it is considered as an excellent table fish and fetches very good price, both in domestic and export market. They are large, pelagic and migratory species inhabiting temperate to tropical waters in the Atlantic, throughout the Caribbean, and in the Indo-Pacific off India, Australia and Japan. In India, they occur along the coastal waters of both east and west coast. Though, there is no targeted capture fishery for this species, it is in high demand as a potential species in aquaculture. Cobia can grow upto 6.0 kg in a year and at present it is being cultured in India, China, Taiwan, the Dominican Republic, Mexico, Philippines, Puerto Rico, United States of America, and Vietnam. Since it is highly sought fish,information on genetic diversity of wild population is an essential for understanding effective management and conservation of the populations of this species. Despite the importance of this species as a valuable marine resource, little is known about genetic diversity and population structure of cobia in the Indian waters. Failure to detect population units may lead to local overfishingwhich induces a rapid loss of genetic variation of target species, which may diminish the adaptability and persistence of the species. Keeping the above points, we undertook the studies on genetic stock structure of the cobia using microsatellite markers. Microsatellite marker is one of the important molecular markers for studying the population stock structure.

In the present study, the genetic stock structure of *R. canadum* distributed along Indian coast (including both Arabian Sea and Bay of Bengal) was identified using hypervariable microsatellite marker. Genetic variation was estimated using 14 polymorphic microsatellite loci captured from east (West Bengal and Tamilnadu) and west (Gujarat and Kerala) coast of India.The total no.of alleles per locus ranged from 7 (RCa1BE08) to 33 (RCa1 H01) and the allele size ranged 104 to 314bp. The mean no. of alleles over all loci, for all populations was 12. The average allelic richness across loci and levels of gene diversity varied between populations 2-22.0 and from 0.10 - 0.95, respectively. The RCa1A08 locus showed the lowest gene diversity (0.105), whereas the RCa1BD10 locus showed the highest gene diversity (0.953). Mean value of expected heterozygosity (Hexp - 0.718) for each population was high compared to observed heterozygosity (Hobs – 0.642). No significant departure from Hardy Weinberg expectations were observed in single locus exact tests after applying sequential Bonferroni correction. Genetic variability reported in cobia populations were high, signifying population is not under threat or decline. The pair wise genetic distance was the highest between Gujarat and West Bengal

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(0.0480). In addition to overall Fst, population differentiation was also estimated using overall Rst estimates based on differences in allele size in microsatellite loci. Overall Fst and Rst values were0.034 and 0.068 respectively, indicating that there is a low genetic differentiation among cobia populations along Indian waters.

AMOVA test containing all samples was undertaken to calculate global FST value. The AMOVA analysis of cobia populations showed no significant clustering between samples similar to pairwise Fst test (P<0.001). The estimated gene flow (Nm) was ranging from 1.914 (RCa1BA04) to 22.423 (RCa1BD10). High gene flow may be due to long distance migration followed by admixture between resident and transient groups. This finding is consistent with observed migratory patterns and tag-and-release studies of cobiaswhich suggested that they are highly migratory and hence should be managed as a single unit.

Knowledge of the genetic diversity and population structure of wild stocks can aid policy design with regard to fisheries and conservation management, as well as selective breeding programs in aquaculture development. Currently, the populations of cobia is under exploited, but the field observations shows that most of the cobia landed at different harbours are mostly juveniles/under sized or they are captured before they reach the first maturity.The growth in overfishing faced by this species may lead to a subsequent decline in wild populations. The information from this study may aid to formulate management policies and fishing regulations to conserve the resources.

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MECOS 2 |MFMP 31

Occurrence of hermaphroditism in Indian mackerel, *Rastrelliger kanagurta* (Cuvier)

Dhanya, A.M *, Preetha G Nair, K. S. Abhilash, V. P. Pravitha, Dhaneesh Vijayan, P. G. Vishnu, P. Shamal and V. Kripa
Central Marine Fisheries Research Institute, Kochi 682 018, Kerala, India. Email: dhanya.am@gmail.com

The Indian mackerel *Rastrelliger kanagurta* (Cuvier) is one of the most important pelagic fish and has a second position among pelagic resources of south west coast of India and it is a multispawner. Mackerel is heterosexual and possible to distinguish the sex of the fish when it is about 120 mm. Hermaphroditism is a condition where the male and female gonads are observed in the same individual and has been reported in several fishes. The gonads may be functional at the same time or at different times or sometimes may not be functional

This is the first report of hermaphroditic mackerel from the Kerala coast. During regular biological sampling of mackerel from fish landing center at Kalamukku, Vypin, Kerala, two instances of hermaphroditism were observed. The first one was on 6th February, 2014 in a specimen caught by gill net operated off Kochi and the second one on 6th June 2014 from the same landing centre from a ring seine catch operated in almost the same area (Lat. 090 59' 49.93"N. Long.76002'30.73"E.). The fish samples collected from the landing centre were taken to the CMFRI laboratory and after recording their

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total length and weight, their maturity stages were observed as per standard fishery biology methods. The gonads were carefully removed, their weights noted and stages identified based on microscopic examination of the gonad smear. Concurrently the fecundity and ova diameter of both the hermaphrodite and normal gonads were done followed by gravimetric method. For the histological analysis, the gonads of hermaphroditic specimens and normal specimens were fixed in 10% neutral buffered formalin and dehydrated in ethanol series and the cleared samples were embedded in paraffin wax and made in to blocks. Serial sections of $5 \mu m$ were taken using a Leica Microtome and stained by Harris haematoxylin and eosin.

In the case of first instance the hermaphroditic gonads were observed in fish with a length 178 mm and weight of 52 g. The gonad was clearly formed by separate testis and ovary and they were not interconnected. The length of the right ovary was 33mm while the left ovary was smaller, 22 mm. The total weight of testis and ovary were 0.67 and 2.82 g respectively. The gonads were in fully spent condition. Histological analysis showed that the ovary and testis were similar to other normal gonads and they were in spent stage. The second hermaphroditic mackerel identified has a length of 190 mm and weight of 83 g with fused male and female gonads. But the ovary was dominant and was encircled by the thin testis. The length of the ovary was 32 mm and the total weight was 2g. Histological studies showed that the female gonad was prominent and that the testis was not well developed.

All these collected biological and histological data were compared with the normal gonad of Indian mackerel which showed that the fecundity was low (26,966) compared to that of normal gonad (42,276). The ova diameter of hermaphrodite ranged between 226- 780 mm and in normal gonad it was 200 to 667 mm which clearly indicated that there was not much variation in ova diameter. Histological and ova diameter studies showed that the hermaphrodite gonad contained immature, maturing and spent staged cells.

MECOS 2 |MFMP 32

Reproductive aspects of incirrate octopus *Amphioctopus neglectus* (Nateewathana & Norman, 1999) exploited in eastern Arabian Sea

Geetha Sasikumar*, G. Sampathkumar, S. P. Karamathulla and M. U. Shivappa
Central Marine Fisheries Research Institute, Mangalore Research Centre, Mangalore, Karnataka 575 001, India. Email: gs.pallath@gmail.com

Owing to their export demands, octopus resources have emerged as important component in the commercial trawl fishery of eastern Arabian Sea. The aspects of the reproductive biology of this incirrate octopus in the eastern Arabian Sea are described in this study. A total of 3,246 individuals of *Amphioctopus neglectus* were examined, during November 2007 to December 2011 ranging in Dorsal Mantle Length (DML) from 22 to 105 mm to study reproductive characteristics.

Maturity stage was assigned macroscopically considering the gross morphology of the gonads and the associated glands. Maturity stages were classified on a 4-point scale of I-IV as immature (I), maturing (II), spawning (III) and spent (IV) stages. The spawning seasonality was determined based on the monthly changes in the percentage frequency of the maturity stages and the mean monthly values of the gonado-somatic index (GSI).

Males with ripe gonads were encountered in the trawling grounds throughout, (representing 69% of samples) suggesting year-round maturation. The percentage of males in ripe stage exceeded 90% in April. Higher proportion of males with spent gonads peaked in June and those in immature stages were minimal in the population. The proportions of pre-spawning females were generally below 40%. Percentages of pre-spawning females in trawl catch were 45% in October, 47% in January followed by the highest percentage (57%) in May. Post-spawning females were not observed in the fishing ground during the study period.The GSI ranged between 0.08 and 24.3% body weight (BW) in females and between 0.2 and 14.1% BW in males (Fig. 1). Mean size at maturity ($L_{m50\%}$) was 39.51 mm for males; 68.2 mm for females and 49.68 mm for (Fig. 2).
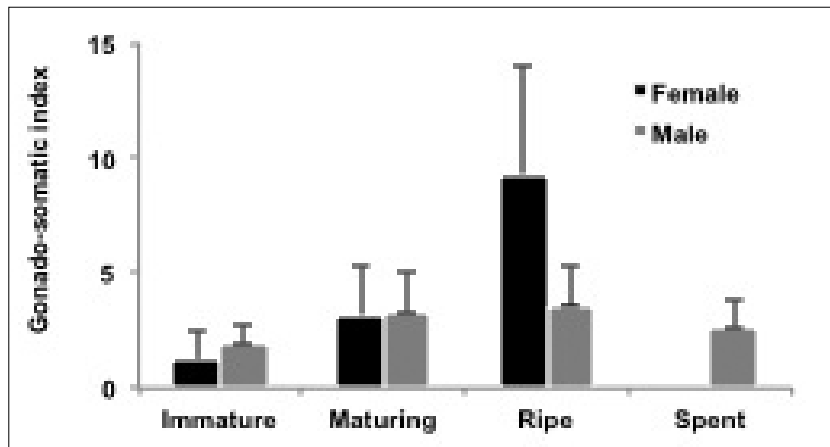
Fig.1. Mean (±SD) gonado-somatic index by maturity stages in *A. neglectus*
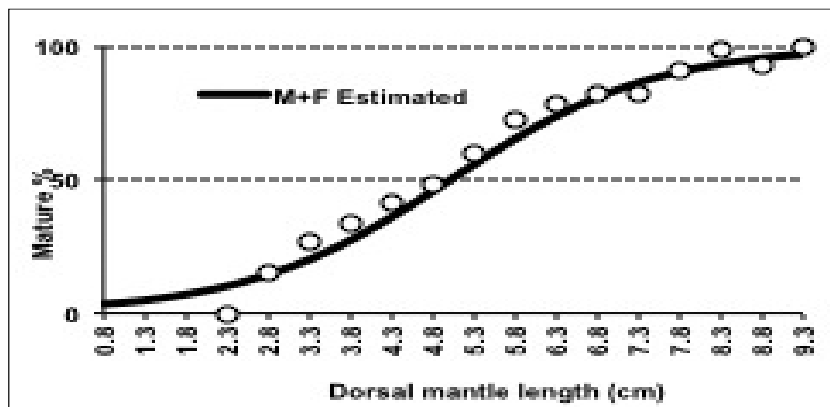
Fig.2. Maturity ogive for *A. neglectus* population

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The smallest mature individuals sampled were 30 mm DML for males and 42 mm for females. The length of the oocytes ranged between 0.8 and 3.96 mm, with an average of 2.44 mm (SD±0.62). The potential fecundity in pre-spawning individuals with DML 58-96 mm was 3,278–23,879 oocytes, with mean of 10,173 (SD ±6,070). The absolute fecundity (deduced from the prominent oocyte-length modes) ranged from 1,070 to 23,879 oocytes with a mean of 9,440 (SD ±8,468). Relative fecundity ranged from 62 to 204 oocytes/g BW, with a mean of 135 (SD±47) and it was dependent on female BW as well as DML. The non-linear least square fit of DML and fecundity relationship of *A. neglectus* was potential fecundity= 5E-05.DML4.3208 (R^2 = 0.64).

Numerical differences in male to female ratios ranged between 1:0.4 and 1:0.9 across the years. The χ^2 test showed significantly ($P<0.05$) greater proportion of males (1,943) than females (1,303) with an overall ratio of 1:0.6 (M:F). The percentages of females were generally less than 60% during January to June months. This differential sex ratio, with fewer females suggests their absence in the trawling grounds especially from January to August months. It is therefore quite possible that the females move into the crevices and sheltered areas for brooding. The males are hence possibly subjected to greater fishing mortality in the trawling grounds.

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MECOS 2 |MFMP 33

Fishery and dynamics of the speckled shrimp *Metapenaeus monoceros* (Fabricius, 1798) along the Kerala coast, India

Lakshmi Pillai, S.*, G. Maheswarudu and M. Radhakrishnan
Central Marine Fisheries Research Institute, Kochi 682 018, Kerala, India.
Email: slakshmipillai@rediffmail.com

Species belonging to the genus *Metapenaeus* is commercially exploited by trawlers along the Indian coast. *Metapeneus dobsoni* is the dominant penaeid shrimp resource that contributes to the major share (40%) of the penaeid shrimp landings of Kerala. *Metapenaeus monoceros* and *Metapenaeus affinis* are the other two species of commercial importance caught in trawls. The former formed about 8-9% during 2011-2013. These non conventional species of shrimps started appearing in the trawl fishery of Kerala during the early 90's with the introduction of multiday and night trawling extending to a depth of 60 m.

Assessment of the population parameters of the species was done using length frequency data collected from commercial trawl landings during Janaury, 2011 to December, 2013. The landings was 2275 t in 2011 which increased to 2660 t in 2012 and then decreased to 2338 t in 2013, the average annual landings being 2424 t. The length range of the species in the fishery was 66 mm to 175 mm for females and 71 mm to 150 mm for males with the modes at 98 mm for females and 83 mm for males. The growth parameters were analyzed using FiSAT

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II software. The parameters obtained for two sexes, females $L\infty$: 182 mm; K: 1.55 yr^{-1} and males $L\infty$: 158 mm; K: 1.50 y^{-1}. The probability of capture was L_{75}:101.7, L_{50}: 96.57, L_{25}: 91.4 for females and L_{75}:97.3 mm, L50: 93.6 mm and L_{25}: 90.0 mm for males. The mortality coefficients were M: 1.42; F: 5.49; Z: 6.90 for females and M: 1.44; F:5.40; Z:6.84 for males. The resultant exploitation rate was 0.79 for both the sexes indicating exploiting well above sustainable levels. Beverton and Holt yield per recruit analysis revealed 50% exploitation level (E_{50}) as 0.37 for females and 0.39 for males. As present exploitation rate is higher than the Emax, it is suggested to reduce the fishing effort by 50% to sustain the fishery.

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MECOS 2 |MFMP 34

Biology and stock status of green tiger prawn, *Penaeus semisulcatus* de Haan 1844 from the trawl fishery of Tuticorin, southeast coast of India

Sarada, P. T.* and K. John James
Central Marine Fisheries Research Institute, Tuticorin Research Centre, South Beach Road, Tuticorin 628 001,Tamil Nadu, India. Email: ptsarada@yahoo.com

The total penaeid prawn catch of Tuticorin during the period 2010-2013 varied from 553 t to 780 t with an average of 699 t. This formed 3-4 % (average 3%) of the total penaeid prawn catches of Tamil Nadu. At Tuticorin 88% of the penaeid prawns was caught by mechanized one day trawlers whereas in total penaeid prawn catch of Tamil Nadu, the contribution by that gear was 58%. The monthly catch of penaeid prawns in trawl net ranged from 30 to 80 t and the monthly percentage contribution of *Penaeus semisulcatus* fluctuated between 59 and 100% with an average of 83%. In the annual catch it formed 72 to 91% with an average of 86%. The main fishing season of *P. semisulcatus* was from June to January with a peak in August.

For biological studies, data collected during 2010-2013 from Tuticorin fisheries harbour was used. The total length of *P. semisulcatus* ranged from 71 to 215 mm in males and 71 to 260 mm in females. The mean length fluctuated between 108 mm and 158 mm in males and 127 mm and 197 mm in the females. Males dominated in the total catch (52%) and the monthly variation of sex ratio was found significant at 0.05 levels. In males, matured ones dominated in all the months and in the total catch it formed 93%. In females also matured ones dominated in the total catch (70%). Spawners were recorded throughout the year with peaks in June and October. The size at first maturity in males was 103 mm and that in females was 132 mm. Empty stomach condition dominated in almost all the months (76%) followed by poorly fed condition (19%) and well fed condition (5%).There were crustacean remains in unidentifiable condition (37%) followed by sea grass (20%), molluscs (19%) digested (10%), detritus (4%), crab (6%), prawn (2%), fish (2%) and sea urchins (1%).

The growth parameters were 241mm (L_∞) and 1.8 (K) for males and 266 mm ($L\infty$) and 1.8 (K) for females. The natural mortality rate (M) was 2.4 and 1.7 for

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males and females respectively. The MSY was obtained at f-factor 0.8 whereas the MSE was obtained when the f-factor was reduced by 40% (f-factor 0.6) from the present level of fishing. The spawning stock biomass (SSB) at the MSY level was 21% for males, 17% for females and 18% for the total. At MSE level the spawning stock biomasses were 26 % for males and 24% for both females and total. At the present fishing level, these values were 17%, 13 % and 14% respectively. However, 20% of the spawning biomass with respect to the virgin spawning stock could be retained in the stock by reducing the fishing mortality by 30% from the present level.
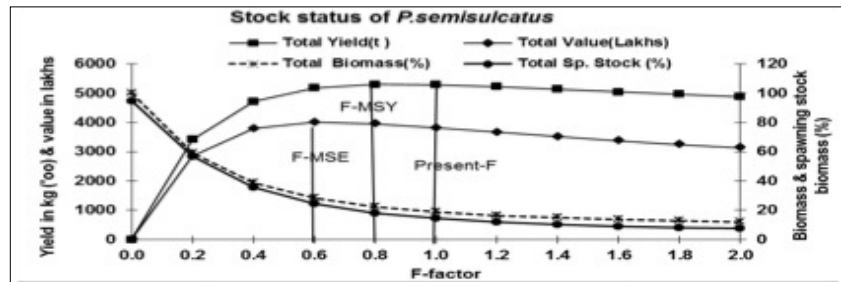
Fig1. Stock status of *P. semisulcatus*

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 MECOS 2 |MFMP 35

Fishery, biology and population parameters of deep sea prawns from Tuticorin, south east coast of India

Sarada, P. T. * and K. John James

Central Marine Fisheries Research Institute, Tuticorin Research Centre, South Beach Road, Tuticorin 628 001, Tamil Nadu, India. Email: ptsarada@yahoo.com

The deep sea prawn fishery by trawlers of Tuticorin was started in 1987 but it was established as a regular fishery only during 1993-94. Though the catch of non-penaeid prawns of Tuticorin showed wide fluctuation from 35 t to 1014 t during the period 2002-2009, it showed a gradual increase from 2010 to 2013 from 541 to 1941 t. The present study is based on the data collected from the deep sea trawlers of Tuticorin fisheries harbour during the period 2010-2013. The number of trawlers involved in deep sea prawn fishing in each day varied from 6 to 15. The average annual CPUE was 502 kg. The fishing ground was 26 miles away from the coast and the fishing depth varied from 290 to 500m. The main fishing season was from November to April. Deep sea prawns formed 67% of the total prawn catch of this centre.

Plesionika quasigrandis dominated (42%) in the catch followed by *Solenocera hextii* (26.7%) and *Heterocarpus gibbosus* (21.9%). The other species were *Aristeus alcocki* (2.435%), *Parapenaeus fissuroides indicus* (0.04%), *Penaeopsis jerryi* (0.409%), *P. martia*, (0.084%), *Metapenaeopsis andamanensis* (2.91%), *M. coniger* (0.033%), *P. investigatoris* (0.49%), *Haliporoides spp.*(1.36%) *H. woodmasoni* (0.59%), *P. longipes* (0.01%), *S. choprai* (0.02%), *S. crassicornis* (0.001%), *P. rectacuta*

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(0.02%), *S. koelbeli* (0.01%), *S. alfonso* and *Nematopalaemon tenuispines* in very negligible quantities. The total length of deep sea prawns ranged from 36 to 170 mm. The mean size of dominant species showed a reduction from November to April.

Table 1. Size range (total length in mm), sex ratio and maturity condition (females) of different species

	Size range	Sex ratio (%)		Maturity condition (F %)	
Prawn	mm	Male	Female	Immature	Mature
A. alcocki	76-170	2.0	98.0	18	82
P. spinipes	46-120			72	28
P. martia	53-115			75	25
H. gibbosus	36-145			58	42
H. woodmasonii	71-110				100
S. hextii	51-140	44.0	55.0	66	34
S. choprai	61-90	25.0	75.0	87	13
S. koelbeli	66-100	39.0	61.0	33	67
S. crassicornis	51-80		100	100	
P. longipes	70-110			100	
P. jerry	66-130	49.0	52.0	100	
P. fissuroides	51-105	77.0	23.0	40	60
P. investigatoris	61-100				
P. retacuta	70-95				
M. andamanensis	61-115	66.0	35.0		
Haliporoides sp.	61-110				
N. tenuispines	61-65				

In *H. gibbosus* minimum size of mature female was 66 mm and berried female was 71mm. Among the matured females 50% were recorded at 88 mm. In *P. quasigrandis* the minimum size of berried female was 68 mm and 50 % of the matured females was recorded at 90 mm. In *S. hextii*, the minimum size of matured female was 75 mm and 50% maturity was at 105 mm. In *S. koelbeli* the minimum size of matured female was 100 mm. In *A. alcocki,*, the minimum size of maturity was 100 mm and at 128 mm 50% of the females were matured. In *P. fissuroides* indicus, those values were 83 mm and 88 mm respectively. The minimum size of maturity in both *H. woodmasoni* and *M. andamanensis* was 91 mm. Empty stomach condition ranged from 56% to 94 % in various species. The stomach contents of deep sea prawns were crustacean remains (3-34%), fishes (0-20%), molluscans (0-5%), foraminiferans (0-1%) and digested/detritus (0-44%).

Length-weight relationships of dominant species were, *S. hextii*: Log W = Log -4.79776 + 2.8498 Log X; *H. gibbosus*: Log W = Log -3.9624 + 2.4324 Log X; *P. quasigrandis*: Log W = Log -4.016 + 2.3346 Log X; *S. koelbeli* : Log W = Log -4.6517 + 2.866 Log X; *A. alcocki* :Log W = Log -4.3007 + 2.5306 Log X;

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P. fissuroides indicus : Log -4.849 + 2.8044 Log X; and *M. andamanensis* : Log W = Log -4.9726 + 2.7932 Log X.

Table 2. Growth parameters, mortality rates, exploitation ratio and size at first capture of dominant species

	L ∞ (mm)	K	M	F	Z	E	L 50 (mm)
H. gibbosus	151	0.83	1.308	3.37	4.68	0.72	81
P. quasigrandis	124	0.56	0.67	1.78	2.45	0.73	83
H. hextii	145	0.54	0.676	1.59	2.27	0.7	96

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Biological loss due to exploitation of juvenile prawns by 'thallumadi' and assessment of their stock sustainability from Tuticorin, southeast coast of India

Sarada, P. T.* and K. John James
Central Marine Fisheries Research Institute, Tuticorin Research Centre South, Beach Road, Tuticorin 628 001, Tamil Nadu, India. Email: ptsarada@yahoo.com

The gears used for prawn fishing along Tuticorin coast were mechanized trawl net, indigenous trawl net ('thallumadi'/push net) and gill net (eral valai). In mechanized trawls, prawns formed only 2% of the total catch and the percentage of juveniles in the in the total prawn catch of that gear was only 3.6. The 'eral valai' are mainly operated in estuarine area for juveniles of *Penaeus indicus* and the catch formed only 2% of the total prawn catch. The main gear involved in juvenile prawn fishery was 'thallumadi' which contributes 6% to the total prawn catch. This is a passive gear operated with the help of wind along the shallow coastal sea grass bed. Though the catch of 'thallumadi' also consisted of juvenile crabs, fishes and cephalopods, the targeted resource was prawns. The annual prawn catch by this gear varied from 15 t to 46 t with an average of 34 t during the period 2010- 2013. The average monthly catch ranged from 1.7 t to 5.2 t with an average of 2.8 t and the CPUE from 3 to 13 kg with an average of 7kg. The peak catch was in May followed by September whereas the highest CPUE was in September followed by November. Among the 17 species that constituted the prawn catch, *Penaeus semisulcatus* formed 92%. In this species, 75% of males and 93 % of females were juveniles (by number). Hence the biological loss due to juvenile fishing was calculated with respect to this species for the period 2010- 2013. The other dominant species constituted in the fishery were *P. latisulcatus* (2.6%), *Parapenaeopsis maxillipedo* (1.3%) and *Metapenaeus moyebi* (1.8%). The size range, sex ratio, and maturity condition of all species are given in Table 1. The biological loss due to juvenile fishing in terms of wet weight was 51 t/ year and that in terms of money was 369 lakhs/ year.

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Table 1. The size range, sex ratio, and maturity condition of prawns landed in 'thallumadi'

	Size range (TL in mm)		Sex ratio (%)		Female Maturity (%)	
Prawns	Male	Female	Male	Female	Immature	mature
P. semisulcatus	31-190	41-205	51	49	96	4
P. indicus	56-125	56-130	43	57	100	
P. latisulcatus	61-120	66-195	45	55	75	2
P. monodon		121-135		100	100	
P. canaliculatus	91-95	96-100	75	25	100	
M. moyebi	31-130	51-150	36	64	92	8
M. dobsoni	61-70	61-70	37	63	100	
P. uncta	76-80	71-96	8	92	100	
P. maxillipedo	31-90	31-95	58	42	96	4
M. stridulans	41-65	26-80	33	67	95	5
M. toloensis	46-75	46-90	22	78	77	23
M. mogiensis	46-70	56-60	100		100	
T. curvirostris		51-75		100	68	32
T. granulosus	46-80	51-90	24	76	66	34
T. sedili	46-55	81-85	20	80	100	
Alpheus rapacida		56-75		100		100
M. equidens		61-65				

Table 2. The feeding condition and stomach contents of 10 species

	Stomach condition (%)			Stomach contents (%)					
Prawns	Empty	Poorly fed	Well fed	Crustaceans	Molluscs	Fishes	Sea grass/ seaweed	Detritus/ Digested	Polychaetes
P. semisulcatus	66	28	6	26	44	1	4	25	
P. indicus	59	37	4	71	4	3		22	
P. latisulcatus	58	37	7	51	30	1		18	1
P. monodon	34	66		20				80	
M. moyebi	77	21	3	52	44	4			
P. maxillipedo	60	38	3	50	10	2	3	35	
M. stridulans	71	29	2	44	39			17	
M. toloensis	92	8		45	13	3		39	
T. curvirostris	96	4							
T. granulosus	74	26		50	6			44	

Study on feeding habit selectivity of Indian mackerel (*Rastrelliger kanagurta*) in West Bengal coastal sea

Isha Das
School of Oceanographic Studies, Jadavpur University, Kolkata 700 032, West Bengal, India.
Email: ishadas2012@gmail.com

Analysis of stomach content is a widely accepted tool to study the food and feeding behavior of a fish species. It also helps to ascertain the trophic level position and the role it plays in the ecosystem. Very limited studies have been done on the selectivity of feeding habit of Indian Mackerel (*Rastrelliger kanagurta*) in the coastal sea of West Bengal. Stomach content analysis of Indian mackerel has been done during the winter season (November, December, January and February) of the year 2012- 2013. Consecutively, the plankton composition of the ambient water, collected from the corresponding fish catch locations was also analyzed. On calculation of the diversity indices (Shannon Wiener diversity index, Simpson's index, Margalef Richness index and Evenness index) of the gut contents and the marine water samples, it was observed that Indian mackerel is a non-selective feeder, i.e. it does not show any selectivity upon its feed. The calculated value of Shannon Wiener diversity index and the Evenness index was 3.6 and 0.35 respectively, which strongly points the non-selective feeding behavior of Indian Mackerel. On the contrary, feeding habit analysis of this fish in other coastal seas of Calicut, Kerala reported it as a selective feeder. Thus, further studies are needed to ascertain whether Indian mackerel is non-selective feeder or its feeding habit may change under different ecosystems.

Stomach contents and feeding habits of *Arius subrostratus* (Valenciennes, 1804) from a tropical estuary, India

Ambily, V* and S. Bijoy Nandan
N. S. S. Hindu College, Mahatma Gandhi University, Changanacherry, Kerala, India.
Email: ambilyv001@yahoo.com

The knowledge of the food and feeding habits of a fish helps in finding out the distribution of a fish population. The study of food and feeding habits of fishes is a continuous exercise because if provides information for successful fisheries management (Agbabika, 2012). Ariidae or sea catfish comprise approximately 130 species that inhabit marine, brackish and fresh water environment (Marceniuk and Menzes, 2007). *Arius subrostratus* (Valenciennes,1840) is a bottom feeding catfish

found in marine waters as well as estuaries and tidal rivers. No detailed study has been carried out on the monthly variation of food items and feeding intensity and other aspects related to food and feeding habits of this species. Thus the present study was aimed to describe the monthly variations in food and feeding habits of *Arius subrostratus* from the Cochin estuary.

Fishes were collected on a monthly basis from Cochin estuary (from Latitude 90 91' N and Longitude 760 32' E to Latitude 90 51'N and Longitude 760 15' E) from April 2011 to March 2012 period. A total of 500 specimens of *Arius subrostratus* ranging in size from 12.5 to 34.5 cm in total length (TL) and 16 to 410 g in weight were studied for various aspects of food and feeding habits. The fresh specimens were brought to the laboratory for analysis and after recording their length, weight and sex, their guts were dissected out, their fullness noted and preserved in 4% formaldehyde. Analysis was carried out by using both occurrence and volumetric methods. The contents of each stomach were washed into a petri dish and the volume of each category of organisms was determined by the displacement method. To evaluate the importance of each food item, the 'index of preponderence' proposed by Natarajan and Jhingran (1961) was followed. This method simultaneously took into account both volumetric as well as occurrence methods and values were substituted and the index of preponderance values were worked out. The gastrosomatic index (GSI) was calculated to find out the feeding intensity. Relative gut length (RLG) gives an idea of the nature of food consumed. The value of RLG was calculated by simply taking the ratio of gut length to total body length. Feeding intensity in *A. subrostratus* was studied by grouping the stomachs into full, ¾ full, ½ full, ½ full, ¼ and empty. The feeding intensity in relation to month was estimated.

The gut content analysis showed that detritus (46.03%) was the dominant food for *A. subrostratus*, followed by crustacean (15.57%), semidigested matter (14.73%), molluscs (12.4%), miscellaneous (11.03%) and fish (0.24%) (Fig.1). The study of stomach content of *Arius subrostratus* reveals that it is a carnivore and feeds mainly on animal matter. Presence of large amounts of sand and mud in the gut contents indicates the bottom feeding habit of the species. The monthly
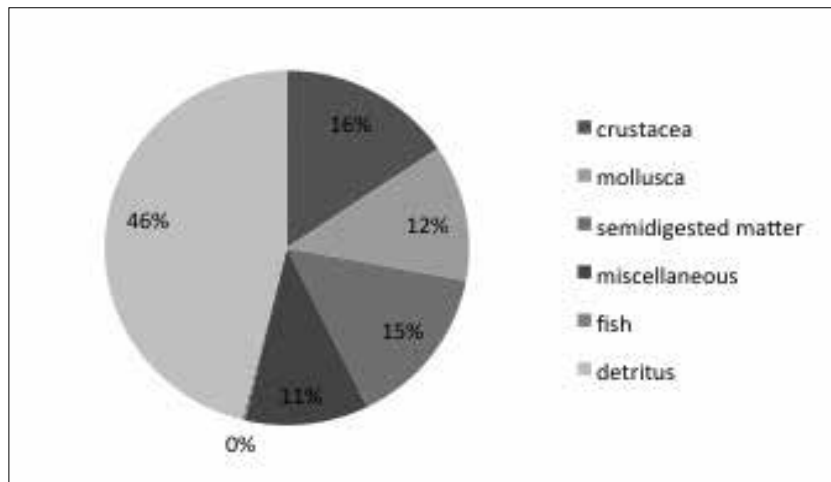
Fig.1. Percentage composition of *A. subrostratus* during 2011 to 2012 from Cochin estuary

percentage distribution of all these food items showed clear fluctuations. The GSI of different months varied from 0.04 to 0.56. Highest GSI were seen on the month October 2011. The RLG values of *A. subrostratus* in the present study ranged from 1.497 to 1.737. The highest percentage of poor feeding intensity (1/4 full stomach) was recorded during December (51.43%), January (51.35%) and March (52%). Active feeding (full and 3/4% full stomachs) was found in July 28.89 % and 35 % in August.

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Relating purple back flying squid (*Sthenoteuthis oualaniensis*) abundance to environmental parameters using GIS and GAM in south eastern Arabian Sea

Mohamed, K.S, K. K Sajikumar*, N. Ragesh, T. V. Ambrose, J. Jayasankar, K. P. Said Koya and Geetha Sasikumar
Central Marine Fisheries Research Institute, Kochi 682 018, Kerala, India. Email: kksajikumar@yahoo.co.in

Purple-back flying squid (*Sthenoteuthis oualaniensis*) is a short-lived, fast growing cephalopod commonly known asthe "Master of Arabian Sea". The distribution pattern of purple-back flying squid and the relationship between abundance and environmental variables in the south eastern Arabian Sea were analyzed using geographical information system (GIS) and statistical modelling (GAM-Generalized Additive Models). The present work aims to develop predictive models of oceanic squid abundance in relation to physical and environmental conditions.

Fishery and oceanographic survey were conducted for exploration of purple-back flying squid onboard MV *Titanic*, a trawler converted to a squid jigger during September 2010-March 2013. Oceanographic and biological samplings were taken from 58 stations during this period. The study covered the oceanic waters from 8°N to 17°N latitudes and 64°E to 76°E longitudes along the eastern and central Arabian Sea at depths ranging from 100 to 4000 m. The environmental parameters measured were SST, Dissolved Oxygen, pH and Chlorophylls which was measured by using a YSI Flurometer (650 MDS). Zooplankton samples were collected by using KC Denmark (Model 23.100-WP-2). A series of GIS maps were produced by using ArcGIS software. Generalized additive models (GAMs) were run in R programme to describe variation in *S. oualaniensis* abundance in relation to geographical and environmental variables.

The GIS maps showed that highest abundance was observed mainly within 14° N, 72°E areas. Temperature was the most important variable, showed strong positive association with *S. oualaniensis* abundance with optimum temperature between 28.03 to 28.80 °C. Salinity (32.70 to 35.08 ppt), Dissolved Oxygen (6.02 to 6.27 mg/litre) and pH (7.75 to 8.30) also showed positive association with abundance (Fig.1). Abundance of *S. oualaniensis* was negatively related to Chlorophyll values. GAM analysis indicated that environmental conditions influence the abundance and also provided a predictive model. The GAM model demonstrates that the

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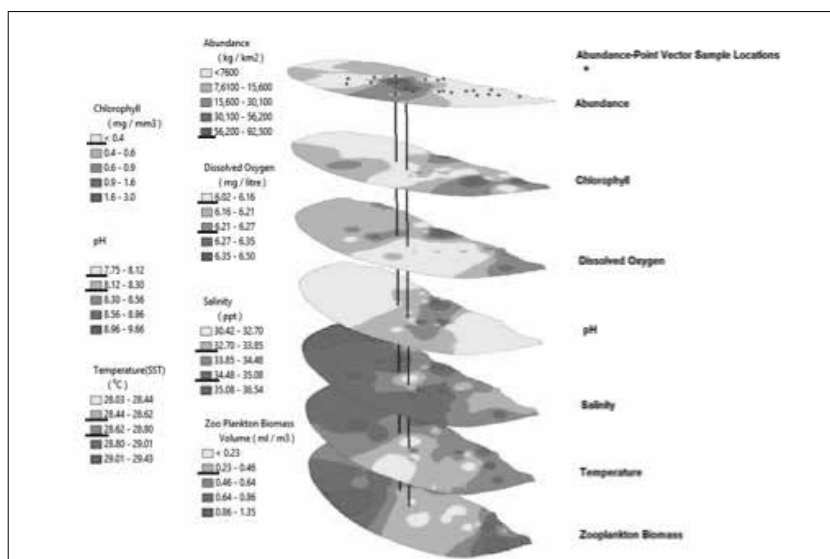
Fig.1 Composite GIS map shows relation between abundance and physico-chemical parameters

relationship between latitude and abundance is highly significant, even though longitude and pH were also significantly related. Model selections were carried out based on the AIC criteria.

The fifth model explained almost 46 % of the variance in purple-back flying squid abundance (Table 1).

Table-1. Sequential goodness of fit measures associated with addition of each term to the abundance model. The best model indicated by bold type.

	R² (adj)	Dev. explained(%)	AIC
Model 1	0.0343	13.08	3587.62
Model 2	0.0656	31.73	3557.23
Model 3	0.0653	36.14	3554.60
Model 4	0.0827	38.93	3555.50
Model 5	0.1200	45.74	3544.70
Model 6	0.1205	46.84	3549.46
Model 7	0.1294	47.73	3554.75

1 Abundance~s(Lat)
2 Abundance~ s (Lat) +s (Lon)
3 Abundance~ s (Lat) +s (Lon)+ s(SST)
4 Abundance~ s(Lat)+ s(Lon)+ s(SST)+ (pH)
5 Abundance ~ s(Lat)+ s(Lon)+ s(SST)+ s(pH)+s(Sal)
6 Abundance ~ s(Lat)+ s(Lon)+ s(SST)+ s(pH)+s(Sal)+s(Chl)
7 Abundance ~ s(Lat)+ s(Lon)+ s(SST)+ s(pH)+s(Sal)+s(Chl)+s(DO)

The outcome of this study suggest that distribution and abundance of the Purple - back flying squid population in the south eastern Arabian Sea was predominantly influenced by spatial and temporal factors and significant association with certain

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environmental parameters such as SST, Salinity and pH, were identified. However, it was clear that the squidabundance was negatively influenced by chlorophyll concentration and more squids were found on the oligotrophic side of the trophic food chain (Low zooplankton density).

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Studies on damsel fishes found along the Vizhinjam coast

Rohini Krishna, M. V.* and M. K. Anil
Central Marine Fisheries Research Institute, Vizhinjam Research Centre, Vizhinjam,
Thiruvananthapuram 695 521, Kerala, India. Email: rohini.krishna09@gmail.com

Species belonging to the family Pomacentridae such as clown fishes and damselfishes dominate the international trade of marine ornamental fishes accounting for 43% of total fish traded. Family Pomacentridae includes about 360 species which occur in coral reef areas and shallow rocky seas. This family comprised of four subfamilies: Amphiprioninae, Chrominae, Lepidozyginae and Pomacentrinae. Family Pomacentridae includes 29 genera of which 250 are damsels. The availability of damsel fish was studied along the Vizhinjam coast for six months. Damsel fishes were collected using hand nets; fish trap and drag net from depths of up to about 4 meters. The average salinity of the seawater ranged from 34-35 ppt and pH from 8.1 -8.3 and water temperature ranged from 28-29°C. Nine species of damsels were recorded from Vizhinjam Bay of this 3 belong to the genus viz., *Abudufduf - Abudufduf bengalensis* (Bengal sergeant); size range out 12-13 cm SL, *Abudufduf vaigensis* (Indo-Pacific sergeant) 9.7-12.3 cm SL , *Abudufduf sordidus* (black spot sergeant) SL 6.0 -6.5 cm, other species include *Neopomacentrus filamentosis* (brown demoiselle) 3.2-9.2 cm SL, *Neopomacentrus nemurus* (coral demoiselle) SL 2.7-9.9 cm, *Pomacentrus cearuleus* (cearulean damsel) SL 3.4-10.5 cm, *Chrysiptera unimaculata* (one-spot demoiselle) SL 5.4-10 cm, *Chrysiptera biocellata* (two-spot demoiselle) SL 9.3- 11.4, *Neoglphiododon bonag* (ocellated damsel) SL - 8.9- 10 cm. *N. nemurus* dominated the collections followed by *N. filamentosis*. In addition to details on the availability, biology of two species namely *N. nemurus* and *N. filamentosis* was also studied and details such as fecundity, spawning frequency, incubation period, parental care and hatching are presented in the paper. Presence of mature specimens of both the species was observed during all the months indicating continuous spawning of these species.

Population structure of *Priacanthus hamrur* (Forsskål, 1775) stocks along the Indian coast using mitochondrial DNA sequences

Vidya, R.*, A. Gopalakrishnan, R. S Biradar, V. S. Basheer, S. Jahageerdar and C. S. Purushothaman
Central Marine Fisheries Research Institute, Kochi 682 018, Kerala, India.
Email: vidya.panicker@gmail.com

Priacanthus hamrur (Forsskål,1775), a marine perch belonging to the family Priacanthidae commonly known as "bulls eye", has started emerging as an important fishery resource in the trawl landings along both the west and east coasts of India. In the present study, the mitochondrial DNA sequences from the Cytochrome b (cyt b) gene were examined to assess the genetic diversity of *P. hamrur* inhabiting Indian coastal waters. A fragment of *P. hamrur* cyt b DNA from each sample collected from 5 representative regions along the coastal zones was amplified by PCR and subsequently sequenced. The results of sequence analysis determined the existence of variations in 7 single nucleotide sites within the 422-bp fragment of the cyt b gene examined in the present study. Phylogenetic trees and pairwise analyses demonstrated a very small divergence (0.43-0.64%) between the populations, suggesting the lack of population subdivisions. The overall lack of genetic subdivision among samples was also detected by the analysis of molecular variance and pairwise Φ_{ST} values. Furthermore, the results of this study revealed a pattern of high nucleotide homology among the adjacent populations and a small number of nucleotide changes among disjunct populations, leading us to conclude that there is a genetic admixture among the populations of *P. hamrur* inhabiting the coastal waters of India.

Fishery, population characteristics and growth of the Crucifix crab, *Charybdis feriatus* (Linnaeus, 1758) from the Cochin coast, India

Jose Josileen*, P.P. Manojkumar, K.P. Said Koya, G. Maheswarudu, P.K Baby and M. Radhakrishnan
Central Marine Fisheries Research Institute, Kochi 682 018, Kerala, India. Email: drjoslin@gmail.com

Majority of the Indian marine edible crabs belong to the family Portunidae, and are widely distributed along the Indian coast. *Charybdis feriatus* (Linnaeus, 1758) commonly known as crucifix crab, is an emerging species in the landings in recent years and the most important commercial species of the genus *Charybdis*. It grows

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to a maximum size of 20 cm in carapace width and prefers to inhabit area of sandy to sandy muddy substrates at depths from 30 to 60m. In India, overall landing of the species during 2007-13 was 20477 t. The species has a good fishery along the west coast with major contribution from Gujarat and Kerala. At Cochin, landings were fluctuating during 2007-13 and the maximum was 235.6 tons in 2008. Fishery comprised of 36-165 mm (carapace width) size crabs and mean size in males and females was 83.59 and 77.1 mm respectively, during the period. Males were dominating the catch in most of the years and sex ratio for the overall period was 1: 0.82.

The interrelationships between various morphometric characters, viz., carapace width (CW) and length and chelar-propodus length and height in males, as well as CW and length and abdominal width and length in females, were estimated using a total of 1771 crabs. The width/length-weight relationship was studied in both sexes on a total of 3019 crabs using the allometric growth equation of von Bertalanffy. The allometric relationships between the characters of this set suggest that most relationships are positive and highly significant (P ≤ 0.01). The 'b' values for carapace width-weight in males (41-160 mm CW) and females (41-140 mm CW) were 2.999 and 2.940 respectively (Figs. 1-2). The results show an isometric growth pattern for bothmales and females,when all sizes are pooled. However, 'b' values for different size groups in both sexes show a significant deviation from an isometric growth pattern. Probability of capture, yield per recruit, growth and mortality parameters, etc. are also estimated for the species. 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 crucifix crabs along the Indian coast.
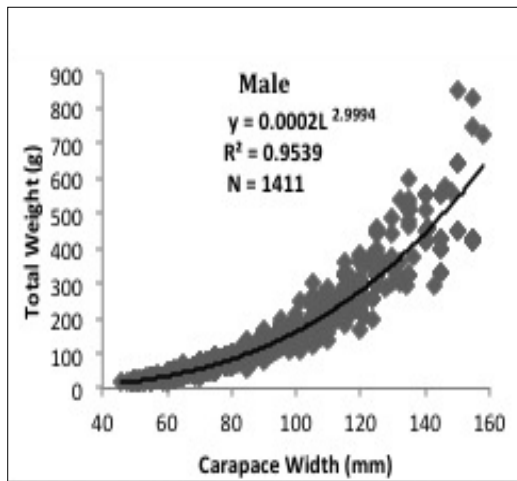
Fig. 1. Carapace width-weight relationship in *C. feriatus* males
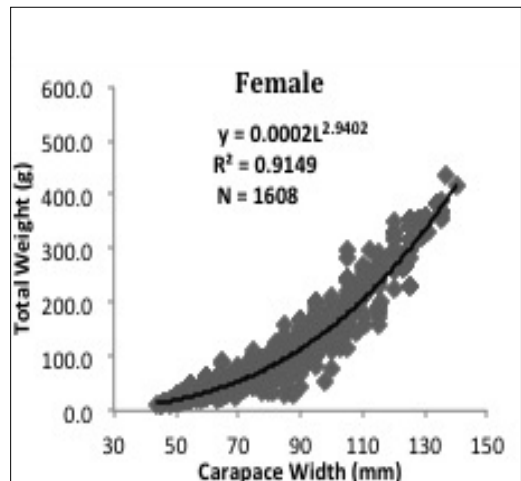
Fig. 2. Carapace width-weight relationship in *C. feriatus* females

Age, growth, mortality and biological study of thinspine sea catfish *Plicofollis tenuispinis* (Day,1877) from Mumbai, north west coast of India

Purushottama, G. B.*, B. N. Katkar, C. Anulekshmi, S. Ramkuma, K. Syamala, S. G. Raje, B. Paramita Sawant, Sujitha Thomas, V. D. Deshmukh and V. V. Singh

Central Marine Fisheries Research Institute, Mumbai Research Centre, Mumbai 400 061, Maharashtra, India. Email: puru44@gmail.com

Plicofollis tenuispinis (Family: Ariidae), commonly known as the "thinspine sea catfish", is an important resource off Mumbai coast, forming about 16% of the total catfish catch during 2004-2013. The annual catch of *P. tenuispinis* varied from 99 to 594 t in trawl net and the annual average catch rate and CPUE were 0.13 kg/hr and 13.5 kg/unit respectively during same period. In this study, the growth, mortality, yield parameters and reproductive biology of *P. tenuispinis* was studied from New Ferry Wharf fish landing centre off Mumbai during 2007-2011. A total of 2,482 individuals from landings of shrimp trawler operating at depths of 50-70 m were measured between 2007 and 2011.The growth, mortality and yield parameters of *P. tenuispinis* based on 5 year length frequency data collected was analysed. The asymptotic length (L_∞), growth coefficient (K) and t_o were estimated as 612 mm, 0.8 yr^{-1}, and -0.0193 year respectively. From on the von Berttalanffy growth (VBG) parameters, the growth of the fish during 1 to 5 years of its age works out to be as 337, 488, 556, 587, and 601 cm respectively. The longevity of fish was estimated at 8 to 10 years. The rates of total, natural and fishing mortalities were calculated as 2.65, 1.27 and 1.39 respectively, on annual basis. The growth performance index (phi prime index,Φ') was 3.4. The relative yield per recruit study shows that the maximum yield can be obtained at E of 0.55 whereas, the present E is around 0.52. This shows that there is optimum fishing pressure on the stock.

A total of 500 individuals, from 20.2 to 53.8 cm total length (L_T) and 0.99 to 1.73 kg body mass (M_T), were examined to determine biological indices for *P. tenuispinis*. The size-at-maturity (L_{50}) for females was estimated at 30 cm L_T. Dietary analysis of stomach contents revealed that *P. tenuispinis* have a preference for crustacean prey including *Acetes* sp. (60% index of relative importance, I_{RI}), and teleost prey, *Nematopalaemon tenuipes* (0.94% I_{RI}), *J. vogleri* (0.24% I_{RI}). A L_T and M_T relationship pooled sexes was derived as Log W= -3.488174+ 2.710508 Log L (r^2= 0.937, n=500), for male as Log W = -3.825528 + 2.804846 Log L (r^2= 0.953, n=220) and for female as Log W= -3.232419+2.640255 Log L (r^2= 0.924, n=280). The overall M: F ratio was estimated as 1:1.27. The reproductive load (L_m/L_{max}) was 0.5 for female. The catfish fishery collapsed in 1980's along north-west coast of Mumbai seems to be recovered from the indiscriminate trawling and purse seine fishing but onus lies with stakeholders to conserve the revived catfish fishery in future years by following the code of conduct for responsible fisheries dictums.

Population genetic structure of slipper lobster *Thenus unimaculatus* Burton & Davie 2007 in Indian waters based on RAPD and mitochondrial gene sequences

Jeena, N. S.*, A. Gopalakrishnan, J. K. Kizhakudan, E. V. Radhakrishnan, Raj Kumar and P. K. Asokan
Central Marine Fisheries Research Institute, Tuticorin Research Centre, South Beach Road, Tuticorin 628 001,Tamil Nadu, India. Email: jeenans@rediffmail.com

The scyllarid lobster *Thenus unimaculatus* Burton & Davie, 2007 whose aquaculture potential has been strengthened with the successful larval rearing, is one of the most important species contributing to lobster fishery in India. The declining trend in catches of this lobster over the years, as well as collapse of fishery in some regions of the country necessitated an immediate assessment of the stock structure to manage and ensure long-term sustainability of this resource in Indian waters. Except for the works on biology, breeding and stock assessment, the population genetic structure analysis of wild sand lobsters have not been undertaken so far in the country. Hence, genetic stock structure was ascertained with molecular markers using samples of the species from four major lobster landing centres of India viz. Veraval and Kollam (west coast) and Chennai and Visakhapatnam (east coast). Random Amplified Polymorphic DNA (RAPD) and mitochondrial DNA markers (partial sequences of Cytochrome Oxidase I/ COI and Cytochrome b/ CYB genes) were used to detect population differentiation.

RAPD markers showed moderate genetic variability in populations with an overall G_{ST} value of 0.0442, which indicated low genetic differentiation among populations. Mitochondrial DNA markers revealed high haplotype diversity coupled with very low nucleotide diversity within each population, as well as low genetic distance, high gene flow, and high mitochondrial DNA similarity among populations. High mean haplotype diversity (h=0.873, π=0.0063 for COI) observed in this study has been frequently attributed to recent time of divergence for various marine species. The TCS minimum spanning networks showed no geographical clustering of haplotypes. The haplotype diversity in the populations for CYB gene was lower compared to the high values for the same, using COI gene. The low levels of differentiation with non-significant P values (F_{ST} - 0.0468 for COI; F_{ST} -0.1250 for CYB) may be due high connectivity among *T. unimaculatus* populations. The present study revealed the existence of a homogenous population of shovel-nosed lobster *T. unimaculatus* along the Indian coast. Three hypotheses are proposed to explain the results indicating connectivity of populations along the coast. 1) The planktonic larval duration that lasts for 27- 45 days; 2) Coastal current pattern of Northern Indian Ocean associated with North East monsoon coinciding with the peak breeding season of species, which can carry planktonic phyllosoma larvae along the coast; 3) Movement behaviour in *Thenus* lobsters. The results of the study will find application in the better management of this dwindling resource.

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Quantitative analysis of marine fish landings of Malabar region of Kerala

Manojkumar, P. P.* and P. P. Pavithran

Central Marine Fisheries Research Institute, Calicut Research Centre,Calicut 673 005, Kerala, India.
Email:manojppin@yahoo.com

Malabar region consists of four coastal districts of northern Kerala with coastal length of 293 km. This region is highly productive and is one of the most important areas in terms of marine fish production. The continental shelf area of this part of Kerala is less than 150 m depth. Malabar area is well known for fishery of oil sardine, Indian mackerel, ribbon fishes, tunas, malabar sole, threadfinbreams, cephalopods, penaeid prawns and green mussel. The major gears used are trawls, ring seines, gill nets and hook and lines. The data on catch, effort and species composition collected from Malabar region by CMFRI for the period 2004-13 was used for this study.

The annual average marine fish production from this area was 2, 55,880 t during 2004-2013 period. The annual landing fluctuated between 2, 05,508 t in 2009 and 4, 17,543 t in 2012 forming 42 % to total marine fish production of Kerala. The gear wise landing showed that ring seine contributed highest with 62% followed by trawl net (28%), gill net (1%), hook and lines (1%) and others (5%). Annual trawler landings fluctuated between 57716 t in 2007 to 117581 t in 2004 with the annual effort of trawl fluctuating between 1468446 hours in 2013 and 2269020 hours in 2004 and the average for this period was 1881122 hours. The catch rate in trawl ranged between 27.2 kg/h in 2007 and 61.27 kg/h in 2004 with an average catch rate was 38.72 kg/h. In hook and lines, the catch ranged between 382 t in 2004 and 4071 t in 2011 and average for this period was 1402 t. The catch rate was high in hook and line, it ranged between 196 kg/u in 2004 and 668 kg/u in 2011 with an average of 388.8 mum kg/u. In ring seine, the catch ranged 122581 t (2009) and 296673 t (2012), the annual effort was minimum 2013 (56133 units) and maximum in 2012 (129538 units). The catch rate ranged between 1260 kg/u in 2004 and 2655 kg/u in 2013 with annual average of 1860 kg/u. Seasonal abundance indicated that maximum catch was recorded during August-October, which accounted 41 % of the catch.

The contribution of pelagic, demersal, crustaceans and molluscs were 75.69 %, 14.36 %, 6.37 % and 3.58 % respectively. It was seen that immediately after lifting the ban on trawling in July, the landing of demersal resources was very high and this trend continues for another 2-3 months. The contribution of pelagic and demersal resources revealed a steady trend in the landings during 2004-2010 which showed an increasing trend from 2011 till 2012, after which the landings started falling. Among pelagic resources, oil sardine (51.9 %), Indian mackerel (8.2 %), scads (2.2 %), *Stolephorus* spp. (2.5 %), other carangids (1.1 %), *Thryssa* (2.4%) and seer fishes (2.1 %) were the dominant resources that formed the catch. Threadfinbreams (5.8 %), soles (3.5 %), lizardfishes (1.2 %), croakers (0.9

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%), silverbellies (0.6%) and rock cods (0.5%) were the major demersal resources found in the catch. Penaeid prawns (4.8 %) and crabs (0.8 %) were the crustacean component found in the fishery, while cuttlefishes (1.3%) and squids (1.2%) formed the important molluscs found in the landings. Miscellaneous fishes and shell fishes were landed in low quantities along with juveniles of various species and other marine resources like echinoderms accounted for about 4.5% of the catch.

Analysis of data indicates that the catch of most of the resources from conventional fishing grounds off Malabar region has reached its optimum level, hence the scope for increasing the catch from the present area of fishing is limited. Bulk of the fishing activity occurs in the 15-100 m depth range. Hence, the extent of fishing pressure exerted on several important resources is very high, considering this there is a need to reorient the focus of the fishing operations along the coast to deeper waters. The studies on threadfinbreams, lizardfishes, eels, deep-sea prawns, bull's eyes and cephalopods have shown promise and the scope for increasing the effort in this direction could help to sustain the marine fish production from this region.

MECOS 2 |MFMP 46

Population dynamics of bigeye thresher shark, *Alopias superciliosus* (Lowe, 1839) off southwest coast of India

Diana Benjamin*, B. Madhusoodhana Kurup and M. Harikrishnan
School of Industrial Fisheries, Cochin University of Science and Technology, Kochi 682 016, Kerala, India
Email: dianabenjamin1484@gmail.com

Populations of sharks have been found to be decreasing in various regions around the world due to fishing pressure and there has been increasing concern about the deteriorating status of the world's pelagic shark and ray populations. Whereas there is some uncertainty about the precise status of these species, there is no doubt that populations have declined significantly as a result of the lack of shark fishing limits in the face of intensive pelagic fishing. Family Alopiidae includes three species of thresher sharks viz., pelagic thresher *Alopias pelagicus*, bigeye thresher *A. superciliosus* and common thresher shark *A. vulpinus*. But only landings of one species under the genus *Alopias* i.e. *Alopias superciliosus* (Bigeye thresher) were observed during the entire period of study regularly and in adequate numbers for carrying out population studies. As there is no information on the stock assessment of thresher sharks from southwest coast of India an attempt is made to assess few stock parameters of the commercially exploited pelagic bigeye thresher shark *A. superciliosus* along the southwest coast of India.

The length frequency data of the bigeye thresher shark. *Alopias superciliosus* for the present study was collected by weekly surveys from Cochin. Munambam, Neendakara harbours in Kerala for the period January 2011 to December 2013. Species identification was based on Compagno (1984), Smith and Heemstra

(1986) and Compagno et al. 2005.A total of 2073 specimens comprising both of male and female individuals of *Alopias superciliosus* in the length range of 55-275 cm were measured during the study period. Length-based stock assessment methods were used for the present study. The monthly length frequency of the sharks was analysed using the FAO-1CLARM Fish Stock Assessment Tools (FiSAT) software of Gayanilo *et al.*, 1997.

Growth parameters of von Bertalanffy growth equation for *Alopias superciliosus* was estimated as L∞= 383.25cm and K=0.43 year-1 in 2011-13. The estimated mortality parameters viz. Total mortality (Z), Natural mortality (M), Fishing mortality (F) in *Alopias superciliosus* were 1.43, 0.50 and 0.93. The M/K ratios of the bigeye thresher shark were estimated to be 1.19 respectively. From the probability of capture analysis, Length at first capture of *Alopias superciliosus* were worked out as 170.98. Results of the VPA using the length frequency data showed that fishing mortality (F) was maximum in the size group of 245-265 cm in *A. superciliosus*. The Relative yield per recruit (Y/R) and Biomass per recruit (B/R) was worked out as 0.44 and 1.19 in *Alopias superciliosus* (Fig 2). Maximum (Y/R)' was obtained at Emax= 0.62 in *Alopias superciliosus*, as the exploitation rate increases beyond this value, relative yield per recruit decreases. The estimated values of $E_{0.1}$ and $E_{0.5}$ in *Alopias superciliosus* were 0.55 and 0.34 respectively. The results indicated that the present levels of E and F were optimum which gives the maximum (Y/R) in *Alopias superciliosus*. The result obtained in this study throws light on the growth parameters of Bigeye thresher shark, *Alopias superciliosus* along the southwest coast of India.

MECOS 2 |MFMP 47

Decreasing trend of length at first maturity (Lm) of Indian mackerel - A comparison over six decades

Preetha G. Nair*, V. Kripa, R. Remya and V. N. Pillai
Central Marine Fisheries Research Institute, Kochi 682 018, Kerala, India. Email: preethagnair@yahoo.in

Rastrelliger kanagurta commonly known as the Indian mackerel is the second largest pelagic resource of Kerala along the southwest coast of India. The fish is mainly caught by seines and gillnets. Mackerel fishery has shown wide fluctuations during the last eight decades and has been found to be influenced by environmental variations. In spite of several low productive years during the period 1980 to 2013 the fishery has not collapsed indicating resilience capacity of mackerel. Heavy exploitation of many fish stocks has produced marked reduction in their abundance and changes in age or size at first maturation. Knowledge of age and length at first maturity (Lm) is essential to evaluate the spawning stock. Considering the importance of mackerel in the State's economy, the study was focused on Lm since this parameter forms an important input in fisheries management. Age at first maturity is an important biological reference point andcan strongly influence the population model and along with the body size is

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an important predictor of the risk of overexploitation.

Concurrently, data pertaining to L_m of Indian mackerel along south west coast of India were collected and compiled from published literature from the year 1940 onwards for the comparison with the present observation. L_m of male and female were estimated as 177 mm and 172 mm respectively. The present study clearly indicates that there is a decrease in length at first maturity of mackerel over six decades. One of the reasons for reduction in Lm can be change in fishing ground and related change in fishing sample. Earlier fishing was more in the inshore waters but now the fishing ground have extended. Other probable reasons can be overfishing, climate change (variation in SST) or other environmental variables along south west coast of India. During the period 1955 to 1977, it ranged between 200 to 220 mm (Table 1) and thereafter, there has been drastic reduction in Lm of mackerel up to the year 2011. It was 172 mm indicating that the fish matures very early in its life. If this trend continues it can affect the fecundity and size of eggs and larvae. Detailed investigations are being conducted to elucidate the major factor for early maturity of Indian mackerel.

Table 1.Details of the previous study on length at first maturity (L_m) of Indian mackerel

L_m of Indian mackerel (mm)	Year	Author	Reference	Station
190	1940	Devanesan and John	*Curr. Sci.,* 9(10)	Madras
210-220	1955-58	Radhakrishnan	IJF 9A (2)	Karwar
224	1956	Pradhan	IJF 3(1)	Karwar
217	1961	Ramamohana Rao	IJF 14 (1&2	Mangalore
223	1977-86	Gopakumar *et al*	IJF 33 (18 & 2)	Vizhinjam
180	1997-2002	Prathibha *et al*	*J. mar. biol. Ass. India*, 46(2)	Mangalore
162	2005	Ganga	PhD thesis, CUSAT	Kochi
173	2006	M. Sivadas *et al*	*J. mar. biol. Ass. India*, 48 (2)	Calicut
196	2006	Ganga	PhD thesis, CUSAT	Kochi
164	2007	Ganga	PhD thesis, CUSAT	Kochi
194	2008	Ganga	PhD thesis, CUSAT	Kochi
170-173	2011	Present study		Kochi

Seasonal variation of sandy shore crustaceans of Mirya Bay, Ratnagiri, Maharashtra

Snehal S. Lokhande*, A. D. Adsul, S. T. Indulkar and R. Pai
College of Fisheries Shirgaon, Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth,
Ratnagiri   415 629, Maharashtra, India. Email: snehal.lokhande147@gmail.com

This study highlights the seasonal variation of sandy shore crustaceans of Mirya bay of Ratnagiri, Maharashtra during April 2011-March 2012. Monthly samples were collected from exposed intertidal region during the lowest low tide. A total of seven macro-faunal species of crustaceans such as Ocypoda cordimana, *O. ceratophthalma, Matuta lunaris, Philyra corallicola, Diogenes miles, Emerita holthuisi* and *Gastrosaccus* sp. were recorded. The total density of crustaceans during pre-monsoon (24.31 no. m^{-2}), monsoon (29.90 no. m^{-2}) and post-monsoon (58.47 no. m^{-2}) was recorded of which, the *Ocypoda* species were abundant throughout the year. The ghost crab (*O. ceratophthalma*) was dominant during April to December, while *O. cordimana* was not recorded consistently throughout the study period. The hermit crab *D. miles* was found near the low tide water mark during all the months except May and June. The moon crab (*M. lunaris*) was observed only during the post-monsoon season (November – December) while the mole crab (*E. holthuisi*) was abundantly found during the late monsoon and post-monsoon seasons. Monthly in-situ parameters observed during study period atmospheric temperature 23.4 to 30.6˚C, interstitial water temperature 22 to 30.5˚C, sediment temperature 22.3 to 32.2˚C, dissolved oxygen of interstitial water 3 to 9.3 mgL^{-1}, interstitial water pH 6.5 to 9.5, sediment pH (5.6 and 8.4) and interstitial water salinity (19.83 to 34.77 PSU).

FISHWARE - A prototype data warehouse for marine fishery informatics

Jayasankar, J., V.K. Manu*, R. Manjeesh and Sindhu K. Augustine
Central Marine Fisheries Research Institute, Kochi 682018, Kerala, India
Email: manu_v_k@hotmail.com

Fishery management has been an area exploding with new approaches and derived methodologies. Starting from simple catch rate based approach to more sophisticated Ecosystem Based Fishery Management tools, these approaches are diversified and information-wise quite demanding. If prediction and "what if" scenarios also are added up to this exercise the resultant scenario needs a strong data feeding mechanism which has information processing capabilities at

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an eminently elaborate scale. This type of data catering scenario is unique in the sense that in this case not only the dimension and the volume of datasets are huge, but also have very high requirement of meta information and granularity based dynamic preprocessing. Such a type of unique database is quite a challenge to conceptualize and execute. This paper makes an attempt at developing a radial architecture based data warehousing prototype as the nucleus of a dynamic, meta data and granularity oriented data smothering enabled data dispensing setup for the requirement of researchers and planners who devise mining based fishery resource management and prediction tools.

The new system, conjecturally named FISHWARE, is built around open source/ shareware DBMS core with auxiliary tributaries as the following:

- Static archived data (varying spatial, temporal and granularity scales)
- Dynamic Archived data (Homogenous granularity)
- Synthetic/ Interpolated public repository based data
- Quasi simulated blocks of data

The proposed FISHWARE model has modules exclusively to deal with spatial and time series inconsistencies of primary datasets generated by research and development agencies as well as government setups. A special module to analytically process the pertinent metadata to suit to mining requirements is added as a vital cog of FISHWARE. Processing modules include provisions to download and decipher shared access datasets in NetCDF, HDF and XYZ formats, which are internationally benchmarked. FISHWARE would comprise instances which logically processes the mining requirements raised by the client, which would aim at data exhaustiveness coupled with speed of processing. Two indices were built up to rate the performance of this prototype under varying data demand scenarios and the performance is also discussed. Such a prototype when lodged as a scalable and clustering amenable, setup would halve the reporting, numerical processing and storage effort required by the research and planning community. The horizontal scalability of FISHWARE is such that it can be easily extended to perform as a Decision Support System/ Advisory Dispensing System for the fishers too.

Aquaculture Production Systems

Track 2

A study on the intrinsic bioremediation potential of an isolate *Bacillus cereus* MCCB 101 in the degradation of organic matter in sediments of shrimp grow out systems

Riya George*, M. Haseeb and I. S. Bright Singh
National Centre for Aquatic Animal Health, Cochin University of Science and Technology, Lake side Campus, Kochi 682 016, Kerala, India. Email: riyageorge1741984@gmail.com

An aquaculture pond sediment isolate *Bacillus cereus* MCCB 101 was found to be promising in bioremediation of organic matter in shrimp pond sediments. The isolate showed high production of amylases, proteases, xylanases and comparatively low production of lipases *in vitro* qualitative assays. The potential of the *Bacillus* in bioaugmenting shrimp pond sediment microcosms *in vivo* at various cell counts viz $10^4, 10^5, 10^6, 10^7$ CFU. ml^{-1} was studied in a bioassay system. The effect of bioaugmentation on total organic carbon (TOC), pH and Eh levels were recorded. The experimental tanks applied with the culture showed upto 36% reduction in the total organic carbon content of sediment samples. Eh got elevated by 40-50% when compared with control tanks where the sediments underwent natural attenuation. The pH was satisfactory throughout the experiment ranging between 7 to 8 in experimental and control tanks. A highly significant negative correlation was found to exist between TOC and Eh in sediments bioaugmented with 10^5 CFU. ml^{-1} than 10^6 and 10^7 CFU. ml^{-1} . Data generated indicated that a single application was sufficient for a span of 10 days after which it had to be replenished.

During the second phase of the experiment *Bacillus cereus* MCCB 101 at an effective cell count of 105 CFU. ml^{-1} of the tank significantly reduced (P < 0.05) total organic carbon by 50% from the initial value in 7th day sediment samples of the bioaugmented tanks than the uninoculated controls. The reduction in the concentrations of total protein, carbohydrates and lipids also peaked by 44%, 53% & 27% respectively on 7th day for the same. Eh increased about 45% in these tanks on 7th day while it improved only by 6.45% in the controls. For an increment of 23 % & 24% in Eh during 4th &10th day in sediments of bioaugmented tanks, only 1.2 % & 0.94% corresponding increase was observed in controls tanks. The total bacterial density as estimated by epifluorescence microscopy in treated tanks sediments were significantly higher than controls (P<0.0001).The average plate counts of heterotrophic bacteria and the Actinomycetes in sediments of treated tanks were also significantly high (P<0.05) than control tanks during the experiment. Thus a concerted action of the bacterial community, asserted by the bioaugmentation accelerated an effective bioremediation in the experimental system as evidenced in our study.

Laboratory and mass culture of a new species of calanoid copepod and its molecular characterization using mitochondrial DNA barcoding

Imelda Joseph, Sarimol, C. N.* and Binoy Bhaskaran
Central Marine Fisheries Research Institute, Kochi 682 018, Kerala, India. Email: saricn88@gmail.com

The present work was aimed to isolate, identify and culture a calanoid copepod from the coastal waters of Cochin, South-west coast of India towards its use as a live feed for larvae of marine finfishes. During the course, a novel species of calanoid group of copepods were collected from Vypeen area of Cochin, Kerala, (N-10° 01.764′; E- 076° 12.955) and identified. Axenised stock culture was maintained for scaling up of the culture. Microalgal species viz, *Tetraselmis gracilis*, *Chaetoceros calcitrans* and *Isochrysis galbana* were fed along with Baker's yeast for the cultured copepod.

For species characterization, the morphological parameters were recorded. The adults measured 100-120 mm and the nauplii 65-120 μm. The life span of
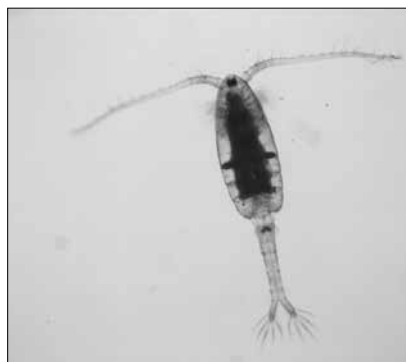
Fig. 1. Calanoid copepod
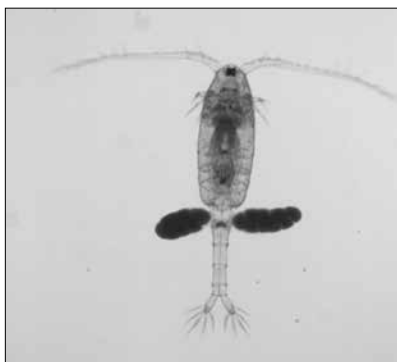
Fig. 2. Copepod with eggs
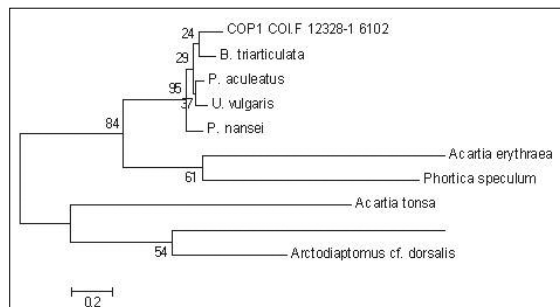
Fig. 3. Phylogenetic tree made in MEGA 6.06 software using Neighbor Joining method

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the species is about 20-25 days with six copepodite stages. The naupli to egg producing stage was 9-12 days. Molecular characterization using mitochondrial DNA was carried out. DNA was purified from individual copepods and ~650-700 base pairs region of the mitochondrial COI gene was amplified using consensus primers (LCO-1490 - 5'-GGT CAA CAA ATC ATA AAG ATA TTG G-3 and HCO-CO-235 - 5'-CCH ACD GTA AAY ATR TGR TG-3') .

Based on the distance matrix and the phylogenetic tree it was inferred that the species (COP1) is related to *Undinula vulgaris* and *Paracalanus aculeatus*. The barcode data from the BOLD System and from BLASTN search implies that the specimen COP1 as a new species with only 83% similarity with *U. vulgaris* and *P. aculeatus*. In other words, in the present barcoding study, the COI barcode sequence divergence of the copepod COP1 was found to be more than 17% with related taxa signifying the fact that the isolated and cultured copepod belongs to new species or genus. The species could be mass cultured up to 5 tonnes and is being used for rearing marine ornamental fish larvae. It has ideal size for feeding marine fish larvae and further studies are in progress.

MECOS 2 |APSO 03

Nutritional profiling of selected micro-algal strains used in larviculture of candidate species of finfish and shellfish used in aqua-farming

Preetha, K.*, C. S. Subin., P. Vijayagopal & K. K. Vijayan
Central Marine Fisheries Research Institute, Kochi 682 018, Kerala, India. Email: preetha.shenoy@gmail.com

Microalgae are the primary producers in the aquatic systems and major food source of larval stages of organisms used in aquaculture systems. Growth and proper development of cultured organism is typically dependent upon their diet. The nutritional value of microalgae is therefore important. Twenty (new and old isolates) microalgae from the MBTD-CMFRI-Culture Collection of Marine Microalgae were analyzed for their protein, lipid, fatty acid and pigment (chlorophyll and total carotenoids) profiles. The isolates were selected based on their growth and stability. Common marine aquaculture strains – *Isochrysis* (2), *Chaetoceros* (2), *Tetraselmis* (6), *Dunaliella* (1), *Nannochloropsis* (1), *Thalassiosira* (1), *Nannochloris/ Picochlorum* (1), *Navicula* (2), *Cyclotella* (2), *Skeletonema* (1) and one fresh water strain - *Spirulina* (*Arthrospira platensis*) were selected for the study. Average protein and lipid contents (Fig. 1) ranged between 11–54 % and 56-10.81% respectively. When compared to *Spirulina* (*A. platensis*-S016 with 45.26% protein) higher % of protein was present in two new isolates of *Chaetoceros* sp. (strains S065 - 54.17% and S172 - 50.98 %), one *Tetraselmis* sp. (S075, old strain - 46.71%), and one *Isochrysis galbana* (S157, new isolate - 50.29%). Maximum lipid content (56%) was recorded in *Nannochloris/Picochlorum*-S170. The total pigment contents (Fig. 2) ranged 0.6-1.6 mg/g of carotenoids and 1.5 – 3.6 mg/g chlorophyll.

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Fig 1. Protein and lipid %

Fig 2. Pigments
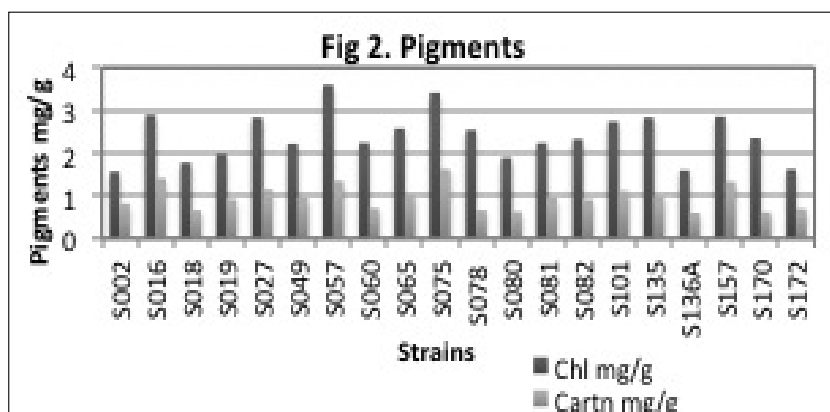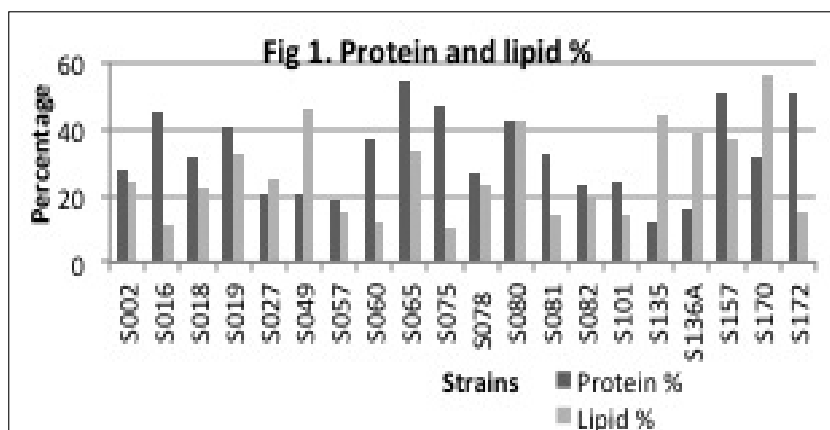
Tetraselmis sp.-S075 had higher pigments – *Chlorophyll* 3.41 & Carotenoids 1.63 mg/g. In fatty acid profiles, total saturated fatty acids (ΣSFAs) range varied from 13.45 to 47.54 %, ΣMUFA (mono unsaturated) from 6.3 to 50.44% and ΣPUFA (poly unsaturated) revealed a wide range from 17.34 to 69.51 %. When compared to diatoms, present study showed higher levels of PUFA% (>46%) in all the selected green algae. Amongst them *Tetraselmis* strains were noted to have good EPA (Ecosapentaenoic acid, 20:5n3 upto 15.07 %) and DHA (Docosahexaenoic acid, 22:6n3 up to 10.36%). As expected *Nannochloropsis* sp.-S078 was having good EPA (15.87%) and *I. galbana*-S157 with good DHA (7.85%). Other major PUFAs like

Arachidonic acid (ARA), γ-Linolenic acid (GLA) and Linoleic acid (LA) were also noted in higher rates in diverse strains – maximum of 5.95% (*Chaetoceros* sp.-S172), 10.23% (*Tetraselmis* sp.-S075) and 15.67% (*Tetraselmis* sp.-S057) respectively. Present study reveals that nutrient profile varied significantly among the strains, indicating that, feeding of larvae with single species or strains, may not meet the individual requirement of candidate species used in aquaculture. Instead, use of multiple strains with compatible PUFA profile of the target species could be a better and preferable option for the production of healthy and quality larvae in hatchery rearing.

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Influence of salinity on mineral profiles in different parts of Pacific whiteleg shrimp, *Litopenaeus vannamei*

Syama Dayal, J.*, M. Muralidhar, R. Jannathulla, K. Ambasankar, E. P. Madhu Babu and V. Chitra
Central Institute of Brackishwater Aquaculture, 75, Santhome High Road, Chennai 600 028, Tamil Nadu, India. Email: syamdayal@rediffmail.com; syamdayal@ciba.res.in

The culture of Pacific whiteleg shrimp, *Litopenaeus vannamei* is increasing rapidly in India due to its profitability and wide salinity tolerance. It exhibits hyperosmotic regulation at low salinity levels and hypoos motic regulation at high salinity levels and effectively maintains ionic regulation. Even though *L. vannamei* is a euryhaline species, wide changes in salinity was seen to affect the growth of shrimp. Farmers are applying various minerals irrespective of water salinity without the scientific basis. In order to understand the mineral profile changes in various parts of shrimp under varying salinities, an experiment was conducted with pre-adult shrimp of 15g size. The experimental animals were acclimatized by changing 2% per day by using freshwater for reducing and crude common salt for increasing the salinities. Experiment was conducted for 15 days after acclimatization to seven salinities viz., 3, 10, 20, 30, 40, 50 and 60%. The animals were fed with feed having 37% crude protein and 6% ether extract throughout the experimental period. Different parts of shrimp such as edible (ED), exuvia (EX), hepatopancreas (HP) and haemolymph (HL) were collected from each treatment after the experiment and analysed for mineral profiles by using ICP-OES.

The levels of Ca, P and Mg were highest in exuvia, since these minerals play an important role in exoskeleton formation whereas the levels of Na, K and Zn were lowest across all the salinities. Edible portion of shrimp had highest amount of K as well as lowest amount of Ca, Fe and Cu than others parts. Hematopoietic elements like Fe and Cu were highest in hepatopancreas indicating the storage functionality. The Ca content was fairly constant between 10 to 40‰ salinity in both edible and exuvia portions. Significantly ($P<0.05$) low and high Ca values were observed in edible and exuvia, and hepatopancreas, respectively at 50‰ and above salinity. The content of Na was highest ($P<0.05$) in 60‰ whereas Mg content was fairly constant in edible, exuvia and hepatopancreas across all the salinities. Ca:P ratio was lowest ($P<0.05$) in edible and exuvia and highest in hepatopancreas at 60‰ salinity. Ca:Mg ratio was significantly ($P<0.05$) low in edible, exuvia and haemolymph, and high ($P<0.05$) in hepatopancreas at 60‰ (Fig.1). In all the parts highest ($P<0.05$) Na:K ratio was observed at 60‰. Based on the present study it can be concluded that salinity has profound effect on mineral profiles in *L. vannamei* and further this data is useful for mineral supplementation studies.
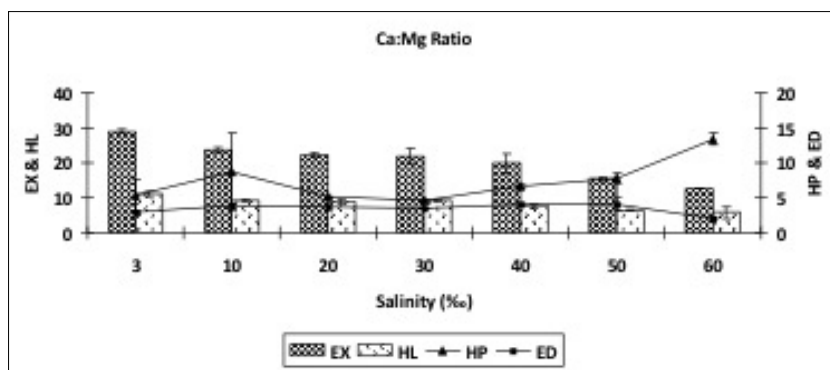
Fig. 1. Ca:Mg ratio of *L. vannamei* at different salinities

Tracing the nitrogen pathway in shrimp aquaculture using ^{15}N stable isotope

Saraswathy, R., M.Muralidhar, J. Syama Dayal, K. Ambasankar, K. Arulmozhiselvan, N, Lalitha, P. Kumarraja, A. Nagavel, P. Ravichandran and A.G. Ponniah,
Central Institute of Brackishwater Aquaculture, 75 Santhome High Road, Chennai 600 028, Tamil Nadu, India. Email:saraswati@ciba.res.in

In shrimp aquaculture,the main sources of nutrients are soil, water and feed. Much of the nitrogen input in the form of feed does not get finally incorporated into the shrimp tissue and majority of it enters the water column, sediment and is deposited on the pond bottom as uneaten feed or faeces. Earlier communication by us on the fate of nitrogen in *Penaeus monodon* culture under zero water exchange system through mass balance approach indicated that 34.2 - 43.6% of nitrogen from feed was converted to nitrogen in shrimp tissueand 16.5-27.3% and 11.2-14% of applied nitrogen was lost into sediment and water respectively. While the link between feed inputs, nutrients and waste loads is well established, little is known about the nitrogen pathway in pond environment, especially the contribution of nitrogen from ingredients of feed to the shrimp tissue. In order to study this nitrogen pathway experiments were conducted to trace the pathway of labelled N by enriching the CIBA shrimp feed with ^{15}N stable isotope.

^{15}N enriched soyameal was prepared by fertilizing the soyabean crop through labelled (^{15}N) 30 atom percent excess (APE) urea. Five different types of shrimp feeds were prepared by incorporating ^{15}N enriched soyameal containing 10.46% ^{15}N nitrogen at various levels (0, 15, 20, 30 and 45%) by altering the fish meal and other protein sources in the feed. ^{15}N assay confirmed that there was an increase in ^{15}N concentration in feed with increasing ^{15}N soybean meal content. The ^{15}N values in feeds ranged between 15.8 and 33.89% (Fig. 1), equivalent to 0.496 and 1.064 APE, respectively.

Yard experiments were conducted with shrimps and ^{15}N enriched feeds in the

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tanks containing water with and without 5 cm bottom soil for 17 days. Survival rate was around 99% in all the treatments. Water, and shrimp samples at the end of the experiment were analyzed for ^{15}N content using Mass Spectrometer.

[15]N contribution from soyameal component of feed towards shrimp ranged from 32.04% to 36.7%, under different ^{15}N enriched shrimp feed treatments in the experiment with only water, whereas in the experiment with soil and water, the ^{15}N contribution in the shrimp varied from 31.10 to 35.42 %. In both the experiments, ^{15}N nitrogen derived from feed to shrimp was high under 30% [15]N enriched shrimp feed (Fig. 1). The tracer studies are useful to understand the fate of N applied and aids in calculating theoptimal requirement of feed for different species.
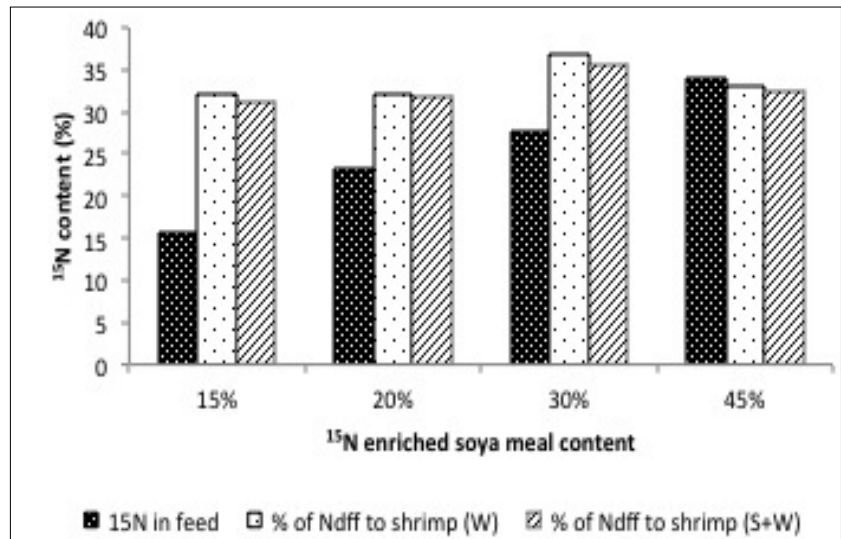
Fig.1.15N content in feed and its contribution to shrimp reared in tanks with water (W) alone and bottom soil + water (S+W)

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MECOS 2 |APSO 06

Effect of stocking density on the growth of Indian pearl oyster *Pinctada fucata* (Gould) spat during nursery rearing in sea

Mary Rinju R and M. K. Anil
Central Marine Fisheries Research Institute, Vizhinjam of Research Centre, Vizhinjam 695 521, Kerala, India.
Email: rinjumary89@gmail.com

Mass production of seed and fully grown oysters are essential for a successful commercial pearl culture. Along with environmental suitability and feed availability, spatial requirement is a critical factor that affects the growth and survival of the

pearl oyster and therefore the economics of the operation. In the hatchery of Vizhinjam Research Centre of CMFRI, gametes of pearl oysters species *Pinctada fucata* were obtained by stripping method. The male and female gametes were pipetted out and fertilization was mediated by 0.5%-0.1N NH_4OH solution at a temperature of 29˚C.The veliger larvae obtained was reared to spat stage in 1 ton capacity FRP tanks feeding with mixed microalgal feed containing *Isochrysis galbana, Pavlova lutherii, Dicreteria* sp. till plantigrade stage and spat were reared with mass cultured diatoms such as *Chaetoceros calcitrans* and *Thalassiosira pseudonana* in addition to the other microalgae.

For studying the spatial requirement on growth on open sea conditions after the nursery phase in the hatchery, pearl oyster spat of average size 13.4 mm dorso-ventral measurement (DVM) and average weight 0.132g were stocked in plastic baskets covered with mosquito netting to prevent escape of spat from basket as they were smaller than the opening in the basket. The basket was of 24cm diameter and 13.5cm height. It has rows of rectangular openings of size 1cm X 1cm on the body and 1cm X0.5 cm openings on the lid. Total volume of the basket was 6104.16 cm³ and total available opening was 700 cm2 for water movement; which brings feed (oysters are filter feeders), nutrients and oxygen in addition to removing the metabolic waste of the stocked spat.

The baskets were stocked at the rate of 50, 100, 150, 200 and 250 spat per basket. Within a month's growth they have reached an average size of 23.5mm, so that the mosquito netting can be removed allowing free flow of water through the cages. At the end of second month they reached an average size of 32.66mm. During period of study, salinity of the pearl farm varied between 33to 33.5 ppt and seawater temperature varied between25.5 to 29˚C.

Morphometric data such as the dorso-ventral measurement (DVM), hinge length (HL) and average weight at the end of first month, second month including the initial measurementsare given in Table 1.

Statistical analysis of the data revealed that the average size of the spat (DVM) at the end of first and second month did not show any significant difference (0.05) at different stocking densities indicating the fact that stocking density can be increased further without compromising growth. The averages showed slightly better growth in lower densities during the first month indicating lower water flows when the cage was covered with mosquito netting. Weekly brushing of the cages during the first month when the basket is covered with netting can improve the growth.

Table 1. Monthly morphometric measurement of *P. fucata* spat

Stocking density	Average DVM	Average HL	Average Weight
	Initial measurements		
	13.96	15.21	0.13
	Measurements after 30 days		
50	26.02	25.88	1.98
100	25.2	25.62	1.84
150	22.04	22.14	1.39
200	21.86	22.36	1.16
250	32.62	22.8	1.29

	Measurements after 60 days		
50	30.76	28.16	3.5
100	32.84	28.28	3.5
150	32.44	29.8	3.21
200	34.72	29.46	4
250	32.62	27.58	3.42

The spat stocked in some plastic basket were found infested with pest like ascidians and sponges which grew profusely over the spat and inner side of the basket, adversely affecting free opening of valves of the baby oysters and water flow through the openings of the basket and recorded retarded growth compared to pest free baskets. To prevent this, fortnightly or monthly cleaning is required depending on the level of fouling. Entry of predators like small crabs and gastropods should be checked fortnightly to prevent mortality of the spat. During the first month when the cage is covered with mosquito netting, weekly agitation and rinsing of cage in seawater is required to remove the accumulated detritus and mud from the basket since their accumulation in some cage adversely affected growth and survival of the stock.

MECOS 2 |APSO 07

Assessment of intra-ovarian egg size and protocols for hormonal induction of silver pompano, *Trachinotus blochii*

Abdul Nazar, A. K.*, R. Jayakumar, G. Tamilmani, M. Sakthivel, P. Rameshkumar, A. K. Samal, V. A. Maharshi, S. Sirajudeen, R. Thiagu and G. Gopakumar
Central Marine Fisheries Research Institute, Mandapam Regional Centre, Mandapam Camp 623520
Tamil Nadu, India. Email: aknazar77@gmail.com

Aquaculture of silver pompano is gaining popularity in India after the successful seed production and farming trials conducted by Central Marine Fisheries Research Institute. Like many other fishes, silver pompano also exhibits reproductive dysfunctions when held in captive condition. The final oocyte maturation and spawning under captivity can be induced by administration of exogenous hormones. The induction of spawning with exogenous hormones like analogue of gonadotropin releasing hormone (GnRHa) or human chorionic gonadotropin (hCG) was carried out after the assessment of reproductive maturity through gonadal biopsy.The dosage of exogenous hormones for spawning induction was same for both males and females. If more than 25 per cent of oocytes had the diameter range of 450 μ to 500 μ, GnRHa at a dosage of 30 μg per kg of body weight was employed for final oocyte maturation.If more than 25 per cent of the biopsied ova measured the diameter of above 500 μ, hCG was administered at a dosage of 350 IU per kg body weight. In the case of GnRHa, spawning was obtained in 40 to 42 hours after administration whereas in the case of hCG, it was within 36 hours. Out of 35 spawning experiments conducted, 74.3 per cent yielded fertilized eggs, 17.1 per cent yielded unfertilized eggs and 8.6 per cent

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did not respond.The water temperature in all these spawning trials ranged from 27.5 to 29.5ºC. It is felt that the size of the intra ovarian eggs can be the deciding factor for hormonal induction strategies which can be employed in hatcheries for successful controlled breeding.

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MECOS 2 |APSO 08

Cultivation trails of marine sponges in cages and indoor conditions of Andaman waters

Kiruba Sankar, R.*, N. K. Chadha, S. Dam Roy, Paramita Banerjee Sawant, Neelam Saharan and P. Krishnan
Central Island Agricultural Research Institute, Port Blair 744 101, Andaman and Nicobar Islands, India
Email: rkirubasankar@gmail.com

The interest in marine sponges has increased rapidly since the discovery of drugs produced by sponges. Their ability to reproduce from small pieces makes sponges very attractive for commercial farming. Aquaculture from explants is the preferred method of cultivation. Marine sponges (*Stylissa massa* and *Liosina paradoxa*) were cultured in situ at Marine Hill Research Laboratory using cages and ex situ in aquarium tanks. Collection was carried out by SCUBA diving and the sponges were collected and transferred into plastic bags under water. Sponge explants were cut into pieces using sterile knife, and the procedure was carried out always underwater as exposing the sponges might lead to mortality. Iron cages ($1 \times 1 \times 0.5$ m) were fabricated with four compartments facilitating to place four substrates (Tile, Block, Coral rock and rope). The cages were laid with polythene coated steel mesh with 1.5 cm mesh overlaid on them to prevent any possible predation (Fig 1). Growth was measured (cm) as increase in length, breadth and height of explants and expressed as increase in volume (Length x Breadth x Height). Measurements were made in situ at cages and aquarium every 15 days for a total of 120 days culture period. *L. paradoxa* in cages recorded significant increase ($p<0.05$) in volume at day 90 by 70% compared to initial volume whereas at 120 days it decreased ($p<0.05$) to 54.22%. *S. massa* showed an significant increase ($p<0.05$) in growth by 95.6% at 120 days compared to initial volume with no shrinkage in growth. The growth of S. massa was significantly ($p<0.05$) higher than that of *L. paradoxa* in cages for 120 days. Thirty-two explants of *S. massa* started with day 0 had 29 explants surviving at 120 days with an average survival rate of 90.62%; however across the substrates coral rocks showed 100% survival rate whereas other substrates tile, block and ropes showed 87.5% survival. In case of *L. paradoxa* out of 32 explants, 27 explants survived with the survival rate of 84.37%. All the substrates showed 87.5% survival at 15 days, whereas in ropes another explants were found dead after a 30 day period. In aquarium tanks *L. paradoxa* showed significantly ($p<0.05$) higher growth when compared to *S. massa* in aquarium. Out of 32 explants of *L. paradoxa*, 30 explants survived at the end of experiment showing highest survival of 93.75% with block and 100% with coral rock in aquarium. Tile and rope showed 87.5% survival as these explants failed to attach the substrates and died. Out of 32 explants of *S. massa*,

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26 explants survived at the end of experiment with overall survival of 81.25% in aquarium. Survival however varied among the substrates used, as coral rocks were found to exhibit 100% survival, whereas tiles showed the lowest survival of 62.5%, blocks with 87.5% and ropes with 75% survival. No feed was added in aquarium tanks and water exchanged every day or possible alternate day. Land based aquaculture of sponges for metabolite production has been attempted for several sponges. Land based systems can provide greater advantage than natural conditions as it is possible to manipulate conditions favourable for the growth of sponges by providing specific nutrients required for their growth and survival. The growth and regeneration studies of *S. massa* and *L. paradoxa* showed that these species can be taken up for mariculture to harness their bioactive potential which will benefit the society owing to their several disease curing capabilities. Suitable site selection with proper care and nutrients evaluation in indoor conditions might improve the survival and growth of marine sponges.
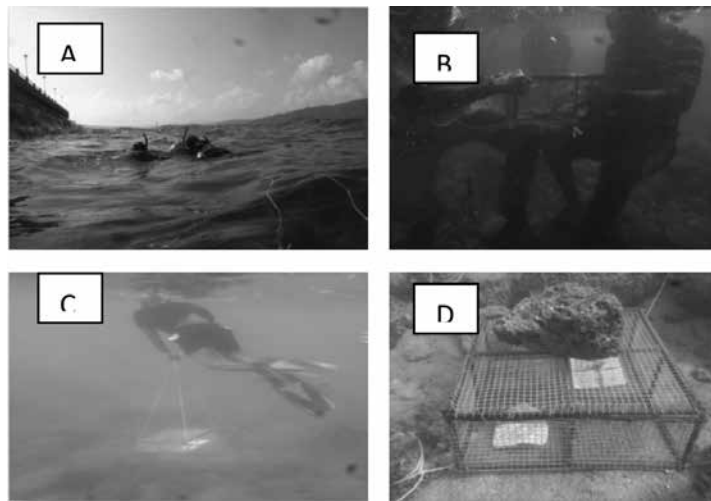
Fig 1. A-B Preparation of Sponge explants underwater at cage site, C- Placing cage at determined location, D- Cage with sponges moored using stone and ropes

MECOS 2 |APSP 01

Growth and production potential of short-neck clam *Paphia malabarica* (Chemnitz) seeds produced under hatchery at Karapad Bay, Tuticorin

Jagadis, I.*, J. Padmanathan, and V. Ashok Maharshi
Central Marine Fisheries Research Institute, Tuticorin Research Centre, Tuticorin 628 001, Tamil Nadu, India.
Email: iyaduraijagadis@gmail.com

Seed production technology for few species of clams in Indian waters such as *Meretrix meretrix, M. casta, Paphia malabarica, Gafrarium tumidum* have been

reported (Narasimham *et al.*, 1988, Sreenivasan and Rao, 1991; Jagadis, 2011). Field transplants of clams especially *M. casta* have been attempted by very few authors (Apparao, *et al.*, 1984, Durve, 1973). However, information on the stock density, growth and survival of the transplanted hatchery produced seeds, intruders in the net pen and the possible total production potential of the clam are negligent.

The present paper details the attempts made to study the above aspects using hatchery produced seeds of short neck clam (*Paphia malabarica*) produced at Shell fish hatchery of CMFRI, Tuticorin in experimental pens (9 sqm each) at Karapad Bay during 2010-2012. Conventional method of spawning and rearing of bivalves was adopted for the clam species. Spawning success in the laboratory was observed during January coinciding with the natural spawning period (lean). The settlement of seed was observed on day 16 post spawning with an average size of 300 μ mm seeds reached an average size of 1.5mm are 70 days rearing in the hatchery with algal feed and was then transferred for nursery rearing. Nursery rearing was done on simple velon bags of (1 x 0.5') placed in a culture cage and hung in the rack erected in the shallow shores of Karapad. After 45 days of nursery rearing the seeds grew to an average size of 3-5 mm. Standard pens of 3x3m were erected in the Karapad bay with PVC tubes and 2.0 mm velon nettings. The bottom of the pen was spread with coarse velon screen and filled over with shore sand. Stocking was maintained at 2000 and 3,500 nos/sqm in different culture experiments. Monthly monitoring for growth and survival of the seed clam was done. The clams at harvest, after 12 months showed an average growth of 3.0 mm/1.1 g with a percentage retrieval of 16.0-31.0. The net production potential of stocked clam seed was worked out to be 7.2 to 9.3 tons/ha in different experiments respectively including other intruders. Experimental results showed the production potential of the bay, in addition to serving as a potential brood stock holding for regular recruitment and sustenance of clam population in the bay.

Table. 1. Growth (mm/wt) of the clams *P. malabarica* at Karapad bay, Tuticorin - 2010-'11

Initial Length (mm)	InitialWeight (g)	Final Length (mm)	Final weight (g)
2.4 – 5.6 (4.3)	0.15-1.1 (0.4)	28.5 – 45.3 (38.2)	6.2 – 24.2 (12.9)

Table.2. Growth (mm/wt) of the clams *P. malabarica* at Karapad bay, Tuticorin - 2011-'12

Pen No.	Initial length (mm)	Initial weight (g)	Final Length (mm)	Final weight (g)
1	3.0-9.0 (3.4)	0.19- 1.14 (0.53)	31.9-43.0 (37.1)	8.6-22.6 (12.6)
2	3.0-9.0 (3.4)	0.19- 1.14 (0.53)	34.8-39.4 (37.2)	9.6-21.5 (14.9)
3	3.0-9.0 (3.4)	0.19- 1.14 (0.53)	38.0-42.5 (39.6)	11.7-24.3 (14.2)
Average	3.4	0.5	37.9	13.9

Table. 3. Production potential of *P. malabarica* at Karapad bay, Tuticorin -2010-11

Nos. Stocked	Nos. survived	% survival	Stock density/m2	Production (Kgs)	Estt. Production/ha
2000	610	31	200 nos	6.5	7.22 tons

Table. 4.   Production potential of *P. malabarica* Karapad bay, Tuticorin - 2011-12

Pen No.	Nos. Stocked	Nos. survived	% survival	Stock density/m2	Production (Kg)	Estt. Production/ ha
1	3500	643	18.4	400 nos	10.0	11.11
2	3500	520	14.9	400 nos	7.5	8.33
3	3500	500	14.3	400 nos	7.5	8.33
Average	3500	544	15.8	400 nos	8.3	9.25

MECOS 2 |APSP 02

GIS-based aquaculture site suitability study for clam farming in Vembanad Lake

Suja, N.* and K. S. Mohamed
Central Marine Fisheries Research Institute, Kochi 682 018, Kerala, India.
E mail: nsuja_r@yahoo.co.uk

The present study identifies and quantifies appropriate sites for black clam farming in the Vembanad Lake using geographical information system (GIS). The GIS has an increasingly important role in management and utilization of natural resources, particularly in fisheries resource assessment and management. Aquaculture has become one of the fastest growing food industries in the world. The black clam, *Villorita cpyrinoides*, is the most important clam species landed in India. Despite being a candidate species for aquaculture, the trials on farming of clams are very limited. Utilization of black clams from Vembanad Lake still relies on collection of wild stock, which has to replenish naturally. A proper culture technique would facilitate relocation of clam seeds to the farming sites, where they could be raised to marketable sizes. It could also reduce the fishing pressure on the natural stock and generate employment opportunities for rural fisher folk, especially women thereby enhancing their economic status. The aim of this study was to select the most suitable sites for clam farming in Vembanad Lake based on the use of GIS-based models to support the coastal zone management decision making process. For this, the importance of each parameter of soil quality, water quality and infrastructure facilities were accessed using analytical hierarchical process. Various thematic layers were prepared for categorizing suitable aquaculture sites based on three sub-models viz., soil quality, water quality and infrastructure facilities. The site suitability map was prepared using each attribute and divided into four classes such as most suitable, moderately suitable, least suitable and poor. The total area covered under this study was 6471 ha out of which, 3121 ha (48%) was identified as most suitable and from the remaining 3350 ha, 1804 ha (28%) was identified as moderately suitable, 946 ha (15%) was identified as least suitable and 600 ha (9%) was identified as poor site for clam farming in Vembanad Lake.

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Effect of dietary vitamin E supplementation on Superoxide dismutase activity and Malondialdehyde levels in *Litopenaeus vannamei* Boone exposed to acute temperature stress

Jefcy Frank and Aneykutty Joseph*
School of Marine Sciences, Cochin, University of Science and Technology, Lakeside Campus, Kochi 682 016, Kerala, India. Email: aneykuttyj@yahoo.co.in

The present study was designed to evaluate the effects of different levels of dietary vitamin E supplementation on some selected immune parameters in juveniles of *Litopenaeus vannamei* using water temperature as a stress factor. Experiment was conducted using completely randomized design (CRD) to evaluate the effect of supplementary vitamin E (0, 100, 200, 300 and 400 mg kg^{-1} feed) under different temperature stress (20 $\pm$ 0.05°C, 24 $\pm$ 0.05°C, 27 $\pm$ 0.05°C, 30 $\pm$ 0.05°C, 34 $\pm$ 0.05°C) on the Superoxide dismutase activity (SOD) and Malondialdehyde (MDA) levels of muscle and gills of *L. vannamei*. Five separate diets containing 0, 100, 200, 300 and 400 mg dl α- tocopheryl acetate (dl α TOA) kg^{-1} diet, respectively, were fed to shrimp (6 $\pm$ 0.5 cm) for a period of eight weeks. Single way ANOVA revealed that vitamin E had significant (P<0.05) effect on the SOD levels in muscle of *L.vannamei*, but no significant effect was seen in the case of gills (P>0.05). The combined effect of Vitamin E and temperature stress was evaluated using Two way ANOVA. It showed that temperature had significant (P<0.05) effect on the muscle and gill SOD levels. Significant (P<0.05) interaction was seen between temperature and vitamin E in both the tissues. However, vitamin E had no significant effect on the gill SOD levels. There was an increase in the SOD levels in the muscle in the various vitamin E supplemented groups when compared to the unsupplemented dietary groups under acute temperature changes. But in the case of gills SOD showed varying levels of activity.

The effect of different vitamin E supplemented diets on MDA levels of muscle and gills showed that vitamin E supplementation could decrease lipid peroxidation (LPX) significantly (P<0.05) in muscle, but not in gills (P>0.05). The combined effect of vitamin E supplementation and acute temperature changes in muscle and gills of *L. vannamei* indicated that vitamin E and temperature had profound effect on the MDA levels of muscle, however only temperature showed significant effect (P<0.05) on the MDA levels in gills. In the absence of vitamin E supplements, a significant increase in the MDA levels was found in the shrimp exposed to sudden temperature changes in muscle and gills. A significant interaction could be detected between temperature and diet in the MDA levels of shrimp (Two way ANOVA, P<0.05).

It can therefore be concluded that vitamin E showed its antioxidant potential in terms of enhancing the activity of SOD and decreasing MDA levels, suggesting that resistance to temperature stress in shrimp fed with vitamin E supplemented diet was stronger than that of shrimp fed with vitamin E unsupplemented diet.

MECOS 2 |APSP 04

Grow-out culture of silver pompano *Trachinotus blochii* (Lacépède, 1801) in marine floating net cages at Mandapam sea, South India

Kalidas, C.*, P. Ramesh Kumar, M. Sakthivel, G. Tamilmani, A. K. A.Nazar, R. Jayakumar, M. Anbarasu, P. Rajandran, R. Thiagu and G. Gopakumar
Central Marine Fisheries Research Centre, Tuticorin Research Centre, Tuticorin 682 002, Tamilnadu, India. Email: dascift@gmail.com

Hatchery produced silver pompano fingerlings of average initial length and weight 10.35±0.5 cm and 29±2.0 grams respectively were stocked in 6m dia and 3.5m depth circular HDPE cages in Mandapam sea on 30th October 2011. The fingerlings were stocked in three growout sea cages at different stocking densities of 15 nos / m³, 10 nos / m³ and 5 nos / m³. The fingerlings were fed with formulated floating pellet feed containing 38 % crude protein and 6% crude fat twice in a day @ 5 % of body weight. Water quality parameters were monitored throughout the culture period. Monthly samplings were carried out and the growth performance was recorded for 10 months, narrated in the below Table.

Table 1: Growth performance of *Trachinotus blochi*

Grow-out culture	Cage-1 (15 nos / m³)	Cage-2 (10 nos / m³)	Cage-3 (5 nos / m³)
Initial			
Length (cm)	10.45±0.3	10.33±0.5	10.65±0.5
Weight (gms)	27±2.0	27±0.8	29±2.0
Final			
Length (cm)	37.0±0.8	39.1±0.5	40.5±0.4
Weight (gms)	600.2±20.2	628.75±12.3	746.75±15.2

MECOS 2 |APSP 05

Incidence of egg predation and epibionts in lobsters

Kizhakudan, Joe K.*, S. Krishnamoorthi, B. Jasper, V. Joseph Xavier, R. Sundar and C. Manibal
Central Marine Fisheries Research Institute, Madras Research Centre, 75 Santhome High Road, Chennai 600 028, Tamil Nadu, India. Email: jkkizhakudan@gmail.com

All marine lobster species available in Indian waters are commercially important. Their breeding biology and life cycle is complex. Females bear the eggs on setose pleopod tips. A curved abdomen into which the ovigerous pleopods bend forms

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a brood chamber for egg incubation. The larvae that hatch out (phyllosoma) get dispersed into the water column. Incubating females are usually less active and remain hidden in burrows, crevices or sand and feed less during the period. They actively comb the setal cluster of eggs and [periodically extrude unfertilized, infected or non-viable eggs. Unfertilized eggs are extruded within 2-7 days intervals depending on the species. During June-August 2014, several egg bearing females of the scyllarid lobsters *Thenus unimaculatus* and *Petrarctus rugosus* and the spiny lobsters *Panulirus homarus, P. ornatus* and *P. versicolor,* held in the lobster breeding facility at Kovalam Field laboratory of CMFRI, were found to discard the complete lot of developing eggs. Sampling of eggs and the clutch revealed infestation by a carcinonemertean worm.

Through a simple technique of washing of infested lobster pleopods, egg clutches and gills, followed by vacuum filtration, it was possible to isolate and identify several epibiont living on the lobsters.

Nemertean worms (juveniles and adults) cause severe losses in the egg clutches during incubation and female lobsters mostly discard the entire lot of eggs irrespective of the stage of embryonic development. Symptoms of nemertean egg predation include white eggs, empty egg shells, worms inside the egg shells and frequent extrusion of eggs. Often the colour of the live worm is the same as that of the host eggs. Egg loss is very severe in infected animals and most of the time the entire clutch is lost. The female lobsters groom the eggs with their fifth pereiopods to maintain the quality and health of the eggs, and can remove eggs which vary in size, density and colour. However the predators try to mimic the host eggs to avoid expulsion. But when infestation rates are more than 20-30 %, the females prefer to shed the entire lot, perhaps as a precaution.

The juvenile worms with their protrusible head and proboscis remain on the gill chamber, the membrane partitions on the integument and on the epifaunal communities on the carapace. Nearly 20-30 adult worms were seen on each brooder egg clutch. They lay their eggs in mucus tubes. They are normally formed in the stalks which bind the fascicles of setae attaching the eggs to the pleopods of ovigerous females. Two eyed knife-like stylet on the proboscis is inserted with the foregut into the egg. The juveniles are found as small larvae on the body and in pilidium larvae associated with ascidian epifauna on the carapace.

Other epibionts were also found to occur, in addition to nemertean worms. Cestodes, nematodes, amphipods, polychaetes, harpacticoid copepods, mites and barnacles were identified in the course of the present study. Among these, amphipods, harpacticoid copepods and barnacles were also found to consume lobster eggs while a host of cestodes, ciliates and filamentous bacteria infest moribund and decaying eggs. However, the intensity of loss was not as severe as caused by the nemertean worms. A comparison on the breeders from the wild and the captive maturation facility is discussed in the paper with remedies on reduction in the infestation rates.

Metal pollution index of water and bioaccumulation of heavy metals in the edible oyster *Crassostrea madrasensis* from a tropical estuary, southwest coast of India

Jenni, B.*, V. Kripa, S. Chinnadurai and K. S. Mohamed,
Central Marine Fisheries Research Institute, Kochi 682 018, Kerala, India. Email: jennihsharma@gmail.com

Azhikode estuary along the south west coast of India is one of the major commercial bivalve farming areas. A study was conducted to quantify the level of metal contaminants in the edible oyster farming water and their accumulation in the farmed as well as natural beds, edible oyster soft tissue in the Azhikode estuary and nearby areas and to compare the levels with EU standards. Four stations were fixed in the farming area based on the proximity to the sea and nine metals such as Zn, Cd, Pb, Cu, Ag, As, Cr, Ni and Hg in the list of EU Council Directive (2006/113/EC, codified version) analysed for two years. Bioaccumulation of metals in oysters were calculated as per the method suggested by Hargrave *et al.*,1997 and is expressed in terms of Bioaccumulation Factor (BAF). Bioaccumulation Factor is the metal concentration in the organism to that metal in the water or the freely dissolved metal concentration.

The main sources of metals in this estuarine system are from the combustion of fossil fuels, SSI units for lead weight manufacture and the leaching of metals from the antifouling paints coated on the fishing vessels. In the first year the highest mean value recorded for Zinc in all the stations followed by Pb>Cr>Cu>Ni>As>Cd>Ag>Hg. The concentration of metals in the farmed oysters as well as in the tissue of oysters from the natural bed and the ambient water showed significant variations in the level of metals they accumulate. Zn recorded the highest BAF in natural bed as well as in farmed oyster tissue followed by Pb and Cu and most of the BAF was highest in the month of April, May, August, November and December when the oysters are in ripe condition.

The level of metals in oyster farming water and its accumulation in farmed as well as natural bed oysters were not alarming and found to be within the limit or below the limit prescribed by EU/WHO/USFDA for bivalve farming and live consumption of bivalves.

The major environmental factors controlling the bioavailability of metals in the water column were observed as salinity and temperature. Accumulation of metal was found to increase with maturity of the oysters. Natural bed oysters were found to have comparatively high values than farmed oysters (Fig.1). The major factors controlling the accumulation were temperature, salinity and reproductive stage of the oyster. Compared to 2009 MPI mean values of water from all the stations, 2010 MPI showed a decrease. But overall for the study period the MPI gradation has showed as station III > station II> station I > station IV (Fig.2).

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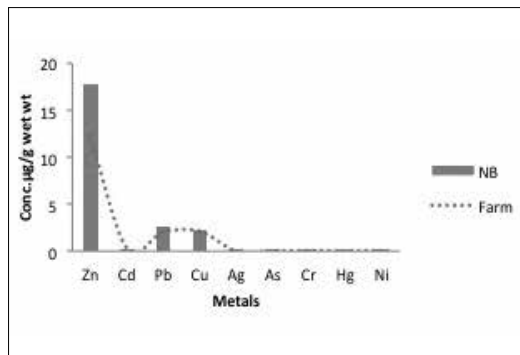
Fig. I. Variation of different metal concentration in natural bed and farmed oyster tissue.
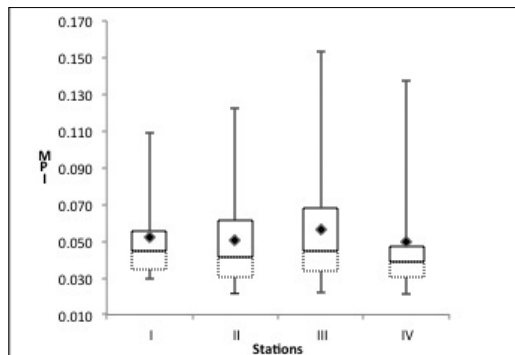
Fig.2. Box and whisker plot of mean MPI with upper and lower quartiles for oyster farming water sampled from four stations. Upper and lower quartiles, Mean MPI, Whiskers indicates highest and lowest values.

MECOS 2 |APSP 07

Stock and mass culture of a calanoid copepod
Pseudodiaptomus serricaudatus

Santhosh, B.*,M. K. Anil, G. Gopakumar, Rani Mary George, K. N. Saleela, S. Vinod, C. Unnikrishnan and H. Jose Kingsley
Central Marine Fisheries Research Institute, Vizhinjam Research Centre, Vizhinjam 695 521, Kerala, India. Email: santhoshars@gmail.com

Copepods are the most abundant live food organisms available in the sea. Copepods are reported to be superior live food organism compared to other commonly used *Artemia* and rotifers especially due to their size, nutritive value and behavioural aspects. Most of the calanoids have smaller pelagic larval forms which makes them ideal for feeding fin fish larvae.

Pseudodiaptomus serricaudatus adults were collected and isolated from a series of zooplankton samples from Vizhinjam bay during March 2012. Pure line cultures were isolated and culture protocols were standardised in hatchery conditions. A mixture of microalgae like *Isochrysis galbana* and *Nannochloropsis oculata* in 1:1 ratio was found ideal for better production. Maintaining feed density of 40,000 to 70,000 cells/ ml is ideal for continuing the growth phase of this species of copepod. Biological factors such as sex ratio, fecundity, life span and life history stages were studied. Females dominated the population throughout the study period and sex ratio in the stock culture tanks estimated was 1: 2.8.

Several stock and mass culture trials were conducted and the results were analysed. Separate stock and mass culture should be there for long term production and maintenance of the stock without contamination. Plastic bins of 100 l capacity were found ideal for stock culture and round tanks of 1000 l capacity for mass culture. Inoculation of 20 l stock culture is found ideal for a mass culture tank of 1000 l capacity. Water volume should only be gradually increased to 1000 litres.

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Dark coloured tanks were found better than light colour tanks. Maximum density obtained in the mass culture tanks were 910-1000 nos/l and this could be sustained in the same culture tanks for a period of 3-4 months but later it was found difficult to maintain the population at that level. It is ideal to start fresh culture in every 5 to 6 months cycle. Procedures for maintenance of water quality parameters, stocking density, feeding, cleaning, rearing and harvesting protocols for the culture of this species in both stock and mass culture tanks were standardised.

Weekly harvesting of naupliar stages by filtering the entire water through 150 micron nets did not affect the population in mass culture tanks. Freshly inoculated tanks of density 50-60 nos/l takes 35 to 40 days to reach a density of 1000 nos /l. Average naupliar production per day per litre was estimated as 720 ± 82 nauplii in experimental tanks from 40-100 days culture period.

MECOS 2 |APSP 08

Mass culture technology for gammarid amphipod *Eriopisa chilkensis*

Maheshkumar, K.*, K. S. Divya and Lita Sunder
Madras Christian College, Chennai 600 059, Tamilnadu, India. Email: mh.kumar1976@gmail.com

Marine ornamental fishes are called as "Living jewels", because of their wavy fins, attractive colours, pattern of feeding and movements with their mates and beautiful eyes. Keeping ornamental fish in a balanced way offers limitless pleasure to all the people, irrespective of age, sex and status. Mimicking the marine environment in an aquatic glass house has its own limitations. In nature, fishes have wide choices for feeding, whereas in the aquarium, hobbyist has to provide a balanced nutritional diet for the growth and reproduction. Food and feed management is the basic criterion for the survival of a fish in aquarium. Among various types of feeds, live feed ranks first in satisfying the nutritional requirement followed by dried feed and artificial feeds.

Amphipods are well suited as live feed organisms. The main factors for success are adaptability and continuous breeding even in the new environment. Amphipods (gammarids and caprellids) are among the most adaptable species in the world. Due to their opportunistic feeding, fast growth and reproductive cycles, their culture would be considerably less expensive compared to other live feed culture. The present study was undertaken to perfect the mass culture technology of amphipods with different substrates viz., nylon fishing net, lava rock and small rock chip structure. Amphipods were maintained in plastic containers (50 l) provided with various substratum and fed with shrimp feed. All the three substrates used in the experiment were found suitable for the growth and reproduction of amphipod. Among the three, the rock chip structure and lava rock showed increase in number of individuals than nylon fishing net.

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Experimental studies on the population density and filtration rate of *Brachionus plicatilis* fed with four marine microalgal diets

Philipose, K. K.*, Jayasree Loka, Krupesha Sharma, Senthil Murugan and S. M. Sonali
Central Marine Fisheries Research Centre, Karwar Research Centre, Kodibag 581 301, Karnataka, India.
Email: kkphilipose@gmail.com

Brachionus plicatilis is the most widely used live feed for rearing of fish larvae in marine finfish hatcheries. An experimental study was carried out on population density of *Brachionus plicatilis* fed with four different concentrations of microalgal cultures. The experiment was designed in 10 litre capacity buckets for a period of 15 days and triplicates were maintained for each feed. The study revealed maximum number of ovigerous females (55 ± 12 ind/mL), population density (215 ± 15 ind/mL) and specific growth rate (1.2 ± 0.05 / day) were obtained for the rotifers fed with *Nannochloropsis* sp. It was also observed that the population density and specific growth rate of rotifers varied with time and concentration. Filtration and ingestion rates of the rotifer were studied to understand the effects of different microalgae densities and feeding times on the feeding behavior of the starved *B. plicatilis* and the study revealed high filtration rate with *Nannochloropsis* sp. followed by *Isochrysis* sp. Analysis of variance showed that the growth rate and population density of the rotifers ($p < 0.05$) significantly varied with the type and concentration of feed. Studies on ciliate and microbial association of rotifers during the study period indicated that the prevalence of ciliate infection also varied significantly with the type of feed and also the ingestion rates ($p > 0.05$). Microbial density of water in rotifer culture tanks varied between 2.8×10^4 cfu/ml to 1.4×10^8 cfu/ml. A positive correlation was observed between the occurrence of ciliate infection and total bacterial loads but no significant variation was observed between ingestion rate of rotifer and total bacterial abundance of water in all the treatments.

Propagation of soft coral *Sinularia kavarattiensis* (Octocorallia: Alcyonacea) at Mandapam, southeast coast of India

Vinod, K.*, Rani Mary George, G. Gopakumar and N. Ramamoorthy
Central Marine Fisheries Research Institute, Calicut Research Centre, Calicut 673 005, Kerala, India.
Email: vinod_kavungal@yahoo.co.in

The soft corals are one of the important organisms in a coral reef ecosystem, having both ecological and economical value. They are rich source of many biologically

active compounds which are found to possess anti-bacterial, anti-inflammatory, anti-tumour and cytotoxic properties. Also, owing to their colourful appearance and structural beauty, they find an important place in the marine aquarium trade. Considering their immense value, developing suitable propagation techniques to produce large number of colonies in captivity, assumes significance. Artificial propagation will ensure lesser exploitation from the wild, steady supply of raw material to the pharmaceutical industries and also for the aquarium trade.

The soft coral *Sinularia kavarattiensis* which is found in the Gulf of Mannar and the Palk Bay is an excellent species for growing in an aquarium. Studies elsewhere have also shown that *S. kavarattiensis* contain bioactive compounds sesquiterpene which has anti-fouling properties and also furano-sesquiterpene which can inhibit the proliferation of several human cancer cell lines.

In the present study, an attempt was made to develop suitable propagation technique for *S. kavarattiensis*. The study was carried out at the Mandapam Regional Centre of CMFRI at Mandapam, south-east coast of India. Tiles and concrete blocks were used as substrata for attaching the lobes that were fragmented from the parent colonies. The type of substratum did not show any difference in the time taken by the explants for attachment. The time taken for attachment is about two to three weeks. The mean increase in basal circumference after complete establishment of the colony to the new substratum was 16.71 mm and the mean increment in the number of lobes was 4.3 in 30 days with 100% survival, under laboratory conditions.

The fully established colonies of *S. kavarattiensis* were tied to plastic cages and suspended in the coastal waters at Mandapam for assessing their survival and growth in open sea. An increment in basal circumference ranging from 80 to 135mm and an increase in the number of lobes ranging from 33 to 98 was achieved in a culture period of 80 days. The present study has clearly shown that colonies of soft coral *S. kavarattiensis* can be produced in large numbers using simple propagation methods.

MECOS 2 |APSP 11

Effect of different application rates of raw cattledung and chicken dropping on water, soil quality and zooplankton population in Kharland ponds

Gangan Shardul, S.*, Pravin H. Sapkale, Sharad D. Patil, Kashinath D. Patil, Amjad K. Balange, Bharat M. Yadav
Taraporewala Marine Biological Research Station, Bandra (West), Mumbai 400 051, Maharashtra, India.
Email: shardul76@rediffmail.com

Experiment was carried out for 11 days in outdoor ponds (25 square meter) following the phase fertilization techniques used in the nursery ponds of Indian Major Carps. Seven treatments were designed with chicken droppings and raw cattle dung is the

ratio 90:10, 80:20, 70:30, 60:40, 50:50, 40:60 and 0:100 respectively. Qualitative and quantitative analysis of zooplankton with the soil and water parameters were compared between the seven treatments (T1-T7) and control (T8). The treatment T1 and T2 yielded significantly higher values of NH_4–N, NO_2–N and significantly lower values of dissolved oxygen than the other treatments. There was significant difference in the total number of mix zooplankton population i.e 2289 no/l and 95.56 percentages in the treatment T4 (40:60 CD: RCD). Zoobenthos population was low in all the treatment. The results of water and soil analysis shows that as the RCD (Raw Cattle Dung) percentage increases and the CD (Chicken dropping) percentage decreases in the treatment, percentage of Organic Carbon increases and vice-versa. Similarly, Available nitrogen from the soil and Total nitrogen from the water increases as the percentage of Chicken dropping percentage increases in the treatment. The results reveals that Treatment T4 (40:60 CD: RCD) is a better combination to use in the Phase fertilization technique of Kharland nursery management of Indian Major Carp. Result point out that treatment T4 shows that the desired water quality and plankton abundance are maintained in the system.

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MECOS 2 |APSP 12

Amelioration of AFB₁ toxicity in *Penaeus monodon* by a dietary herbal spicy mixture

Radhika Gopinath*, U. Unnikrishnan and R. Paul Raj
Central Marine Fisheries Research Institute, Kochi 682 018, Kerala, India. Email: radhikacpg @gmail.com

The spectacular progress scaled by culture of penaeid shrimps have been put at risk by dark clouds of disease manifestations. A feed associated disease in shrimps is due to fungal contamination of improperly stored feeds. Aflatoxins are extremely biologically active secondary metabolites produced by the toxigenic fungi of genus *Aspergillus*. Toxicants have been reported to cause poor growth, physiological imbalance and histological changes in animals. However, there are only few studies which highlight aflatoxicosis in shrimps. Aflatoxin B_1 (AFB₁) is the most potent among naturally occurring carcinogens and the permissible levels of aflatoxin in animal feeds should be below 20 ppb (FDA, 1989). A survey conducted to ascertain the presence of aflatoxins in different feed and feed ingredients from shrimp farms Ernakulam District, Kerala, revealed the presence of aflatoxins in the range of 15- 250 ppb.

A colossal challenge is the detoxification of aflatoxin contaminated feeds as they cause several liver abnormalities in the consumers. The present work focuses on the efficacy of an herbal spicy mixture (Amrita Bindu) in ameliorating aflatoxin B_1 toxicity. Amrita Bindu (AB), an herbal medicine successfully used in detoxification of AFB₁ in rats and fishes formulated by Shanmugasundaram *et al.*, (1994) was used for amelioration in the present study. *Penaeus monodon* of size 11.3 ± 1.24 g were fed four types of diets with one control diet (normal shrimp feed with 38% CP), three test diets for 40 days in separate one tonne fibre glass tanks. Three diets were mixed with additives as diet 2 (500 ppb AFB₁), diet 3 (4% AB with

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500 ppb AFB1) and diet 4 with 4% AB. After the duration, the shrimps were sampled and observed for cellular and humoral factors, histological study of the hepatopancreas and the carcass analysed for retention of AFB1 residues. Statistical analysis was performed using the SPSS 10.0 version for Windows and significance tested by Duncan's multiple range test.

After 40 days of experiment duration, there was reddish discoloration of the body and mortality in the shrimps of Group 2. Reddish discolouration of the shrimp body, a prominent feature of aflatoxicosis in shrimps was not observed in AB administered groups. In Group 3 (Amrita Bindu + AFB_1) and Group 4 (Amrita Bindu), feed intake was more and the animals were more active. The total haemocyte count and total protein levels were significantly lower in group 2 than other treatment groups. Muscle retention studies in shrimps by TLC method showed significant detoxification in AFB1 levels in group 3 when compared to group 2. In group 2 the AFB_1 residue was 52 ppb, while in group 3, the residue observed was 23 ppb respectively. Histological section of the hepatopancreas of shrimp in AB group revealed only mild changes in structure of the tubules when compared to the control group. In the group 2, hepatopancreas showed severe necrosis, detachment and rounding of cells (Apoptosis). Statistical analysis revealed that in most of the parameters, between treatments, control and toxin had higher level of significance. From DMRT, it was evident that in most of the parameters either Group 3 or group 4 formed homogenous set with the control.

Results indicate the usefulness of additives and antioxidants in ameliorating aflatoxin induced toxicity in *Penaeus monodon*.There is no published information on amelioration of Aflatoxin B1 toxicity in *P. monodon*. Detoxification by Amrita Bindu (AB) has proved to be more efficient in the present study as revealed by histological and muscle retention study. From the results it is evident that AB is able to prevent AFB_1 mediated toxicity in the shrimps and detoxify the toxic residues in the shrimp body by 55.76%. Antioxidant and reducing power of the mix may be due to the presence of flavanoids, terpenes, phenolics in the herbs and spices that make up the extract. It is likely that these feed additives act by inhibiting activation of aflatoxins and increasing its detoxification.

Table 1. Composition of the four diets used for amelioration study in *P. monodon*

Groups	Diets	AFB1 levels	Additives used for amelioration
Group 1	Diet 1	-	-
Group 2	Diet 2	500 ppb AFB1	-
Group 3	Diet 3	500 ppb AFB1	4 % AB
Group 4	Diet 4	-	4 % AB

Role of phycosphere bacteria on the growth of *Isochrysis galbana*, an aquaculturally important microalga

Sandhya, S. V*, K. Preetha, Anusree, V. Nair, M. Leo Antony and K. K. Vijayan
Central Marine Fisheries Research Institute, Kochi 682 018, Kerala, India. Email: sandhyavarier@gmail.com

The interaction of specific associated bacteria with microalgae is of great ecological importance since it plays a major role in regulation of algal population dynamics and metabolism. The knowledge on the impact of phycosphere bacteria on the growth of microalgae is essential for improving stability, productivity, sustainability and reliability of large scale microalgal cultivation and their feeding to the target aquaculture species. Only limited studies are available dealing with microalgal-associated bacteria and their interactions. In this regard the present work was aimed to study the role of phycosphere bacteria on the growth of marine microalga *I. galbana*, a common live feed in aquaculture.

Culturable bacteria associated with *I. galbana* culture were retrieved using Zobell's Marine Agar and after incubation, colony counts were taken and morphologically different colonies were selected, purified and screened for their sensitivity towards commercially used antibiotics such as penicillin (P-10 U), streptomycin (S-10 mcg), gentamicin (G-10 mcg) and kanamycin (K-10 mcg) by standard disc diffusion method. The microalgal culture was purified by an antibiotic treatment based on the antibiotic sensitivity pattern of associated bacteria and the growth characteristics of purified (without associated bacteria) and non-purified (with associated bacteria) *I. galbana* culture was monitored by taking cell count at regular time interval using hemocytometer till 21st day. The growth was also compared by estimating total pigment content of purified and non-purified *I. galbana* culture by methanol extraction method. In the presence of phycosphere bacteria there was about 45% increase in the maximum cell density of *I. galbana* culture and the total pigment content non-purified *I. galbana* culture was 13.53± 0.624 µg/ml whereas that of purified culture was only 6.14±0.186 µg/ml. The increased growth rate, biomass accumulation and pigment content of non-purified *I. galbana* culture in our study highlighted the growth enhancing effect of phytoplankton associated bacteria (Table 1 & Fig 1). The results of our study pointed out that a well-characterized combination of bacteria and microalgae can further be explored for broad spectrum applicability in aquaculture.

Table 1: Growth rate of purified and non-purified *I. galbana* culture

Time interval (Days)	Growth rate (r)	
	Purified culture	Non-purified culture
0-7	0.290 ± 0.00	0.280 ± 0.02
7-14	0.04 ± 0.03	0.10 ± 0.03
14-21	0.09 ± 0.01	0.140 ± 0.02
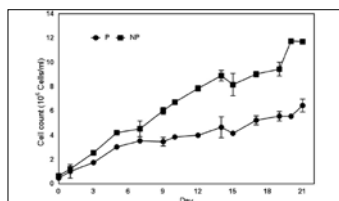
Fig.1. Growth pattern of purified and non-purified *I. galbana* culture

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Effects of photoperiod on growth, survival and feeding periodicity of larval and juvenile *Premnas biaculeatus*

Madhu, K.*, Rema Madhu, T. Retheesh, T. Tinto, M. P. Mohandas and B. Binoy
Central Marine Fisheries Research Institute, Kochi 682 018 Kerala, India. Email: kmadhu30@rediffmail.com

Experimental trials were conducted to determine the effect of extended periods of light on the growth, survival, feeding pattern and daily feed consumption in larvae and juveniles of *Premnas biaculeatus*. Larvae 1-12 days old showed significantly different survival rate, and growth was progressively faster under conditions of 24 h than 8, 16 h light per day. Eventhough larvae of 13-20 days old did not show significant difference in growth between 16 and 24 h light period, significant difference was noted in the survival rates. There was no significant difference in survival rates of juveniles having 11-12 mm total length at 8, 12 and 24 h light period whereas their growth rate showed significant difference. Juveniles exposed to 12L/12D photoperiod were able to feed continuously during light period, and ceased feeding in darkness. Daily food consumption of larvae and juveniles was 60 - 80% in continuous light than in 8, 16 h photoperiod. The results indicate that 24h light increases growth and survival rates during 0-20 days, and later a photoperiod of 12L/12D was suitable up to 30dph and thereafter it becomes less important as it can survive in natural day light.

Microalgae enriched *Diaphanosoma celebensis* Stingelin, 1900 for rearing of larvae and juveniles of *Amphiprion ocellaris*

Rema Madhu*, K. Madhu, T. Retheesh, T. Tinto, M.P. Mohandas and B. Binoy
Central Marine Fisheries Research Institute, Kochi 682 018, Kerala, India. Email: rema.madhu@rediffmail.com

The influence of cladocera *Diaphanosoma celebensis* enriched with different microalgae (*Chaetoceros calcitrans*, *Nannochloropsis oculata*, *Tetraselmis chuii* and *Isochrysis galbana*) was studied in larvae and juvenile of *Amphiprion ocellaris* compared with *Artemia*. The survival and growth of larvae and juvenile were investigated. The influence of these microalgae on the lifespan, growth, neonate production and the nutritional profile of *D. celebensis* were also indicated. Results showed that though significantly higher (P < 0.05) neonate production of *D. celebensis* was attained when fed with *C. calcitrans* compared to the other microalgae longer lifespan was obtained when it was fed on *N. oculata* and *T. chuii*

compared to those fed with *C. calcitrans* and *I. galbana*. Significant difference (P > 0.05) was noticed in larval survival and growth rate of juveniles of *A. ocellaris* when fed *D. celebensis* enriched with mixed algae than unialgae and *Artemia*. This study also indicated that the quality of *D. celebensis* production and proximate composition was highly correlated with the food type, and it can be used as a valuable live feed for clownfish larviculture and juvenile production, and also as a substitute for artemia under captive conditions.

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MECOS 2 |APSP 16

Moult cycle and nocturnal activity of juvenile *Scylla serrata* : a feed rationing and management perspective in mud crab farming

Unnikrishnan, U., Radhika Gopinath* and R. Paul Raj
Central Marine Fisheries Research Institute, Kochi 682 018, Kerala, India. Email: radhikacpg @gmail.com

Like other crustaceans, mud crabs are also known as nocturnal, with greater feeding activity during night. They are highly cannibalistic in the event of prey shortage. Therefore, an effective feed management should be governed by the principles of moulting and nocturnal behaviour of crabs. The literature indicates scarcity of detailed information on the feeding rate and intensity with regard to the moulting and nocturnal behaviour of *Scylla* spp. Therefore, the current study was conducted to unveil the feeding and feed requirement of *Scylla serrata* juveniles with respect to the behavioural aspects associated with moult cycle and nocturnal activity.

Two individual experiments, viz. 1) feeding rate with respect to moult cycle and 2) feeding rate with respect to the nocturnal behaviour were conducted using *Scylla serrata* juveniles (av. body wt. 53.28 ±3.55 g, CW. 50.56 ±2.47 mm), collected from the creeks of Narakkal, Vypeen Island, off Kochi. In both the experiments freshly shucked meat of black clam, *Villorita cyprinoides* was provided @ 10% of the body weight at 1700 hrs daily. The crabs were held in 40 L of fresh seawater (salinity 28 ±1 ppt, temperature 28 ±4° C, pH 8 ± 0.5, DO > 4 ppm, free ammonia < 0.05 ppm). Cent percent water exchange was provided daily at 0700 hrs, along with the removal of left over feed to record the feeding rate. In the Experiment-1, juvenile crabs (n=14) immediately after moulting, were selectively used and ran the experiment for 60-77 days until they moult next time. In Experiment-2, juvenile crabs (n=87) at inter-moult stage (6-10 days past post-moult stage) were used and nocturnal feed intake was recorded by recovering the left over feed at different time points (n=6 to 7) over a period of 14 hrs.

In the Experiment-1, the feeding pattern during the moult cycle (Fig.1) indicates three significantly different (P<0.05) feeding rates, correspond to the post-moult, inter-moult and pre-moult stages respectively. Feeding rate was found to increase gradually after the day of moulting, till the next 4-6 days passing the post-moult stage (0-7.29 ±0.8 %) and reached the maximum (7.54 ±1.28 %) and got stabilized between 4 to 56 days of inter-moult period in juvenile crabs. This is followed by an abrupt decline

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(7.54-0 %) in the 4 days preceding moulting, ie., at the pre-moult stage. The crabs were found to starve the day prior to and about 18-24 hrs after moulting.

The Experiment-2, on nocturnal feeding intensity of the juvenile *S. serrata* (Fig.2) between 1700 hrs to 0700 hrs next morning, revealed two peak intensities. The first one was observed between 1700 and 1900 hrs with about 50% consumption of the ration followed by near zero intensities between 1900 and 2200 hrs, and further showed a gradual increase of about 4.56 % till 0100 hrs and the next phase of improved feed intake extended till 0500 hrs with the second peak consumption of about 18.82% of the ration at around 0300 hrs. The intensity further declined to reach 1-2% between 0500 and 0600 hrs.

The results from the Experiments- 1 & 2 confirm the need of varying feed ration based on moult cycle and also corroborate that the twilight hours are the best time of feeding if single daily rationing is followed. This may considerably reduce the feed wastage, ensuring sufficient feed ration, which in turn guarantee eco-friendly farming, improved crab health, reduced cannibalism and enhanced survival.
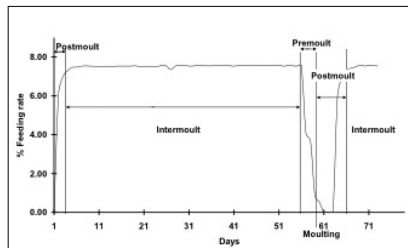
Fig.1. Feeding pattern over the moult cycle in juvenile *Scylla serrata*
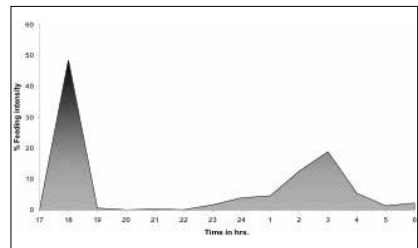
Fig.2. Feeding intensity of juvenile *Scylla serrata* fed single ration of fresh clam meat between 1700 hrs and 0600 hrs

MECOS 2 |APSP 17

Some studies on the live feed mysid *Eurobowmaniella simulans* along the Vizhinjam coast

Neethu Raj. P* and M. K. Anil
Central Marine Fisheries Research Institute, Vizhinjam Research Centre, Vizhinjam 695 521 Kerala, India.
Email: neethurajp08@gmail.com

Mysids are important components in marine and estuarine plankton inhabiting all regions of the oceans. Mysid shrimp, considered to be macro-zooplankton, have their size range from 1.5 to 25 mm in total length. They have been used in mariculture as live feed organism to rear many difficult species which feed exclusively on live feed. Mysids of different size ranges are found suitable as live-feed in the larval rearing of newly hatched squid and cuttlefish larvae, nursery rearing of ornamental fishes, food-fishes and many other marine organisms.

The present study on the availability and biology of mysid was conducted from March 2014 to October 2014. They have been collected using plankton net of

mesh size 200μm. *Eurobowmaniella simulans* is the commonly available species of mysid found along the Vizhinjam coast. Their size ranges between 1.7 mm (post nauplii) -11 mm (adult). Their availability peaked during September and October. During peak season, upto 1.46 lakhs mysids were recorded from a single haul. Availability of mysids was high during early morning hours in the intertidal and surf zones, and their availability drastically reduced after 10am since the mysids got themselves buried in sand or moved to deeper waters as the temperature and light intensity increased during the day time. During rainy days good collection could be made even during noon hours. Monthly percentage availability of brooders and size distribution were also studied and presented in the present paper. Laboratory rearing of *Eurobowmaniella simulans* revealed that they are highly adaptive, and can tolerate a wide range of conditions. Fertilized eggs develop inside the brood pouch and hatch out as a miniature adult. About 20-35 nauplii (eyed larvae) were recorded in their brood pouch. After the incubation period they are released from the brood pouch as miniature mysids of 1.7mm-2mm total length. Despite low fecundity this species has a short reproductive cycle which means they can quickly reproduce in vast numbers. They are found feeding on algae, rotifer, brine shrimp nauplii, copepods, and mussel meat suspension and were reared successfully in seawater of salinity ranging from 25 to 37ppt. and temperature range of 25˚C-32˚C.

MECOS 2 |APSP 18

Some observations on the behaviour and changes in skin colour patterns of Queen coris (*Coris formosa*) juveniles reared under captivity

Sugi, V. V.*, M. K. Anil, S. Jasmine, Rani Mary George and V. Kripa
Central Marine Fisheries Research Institute, Vizhinjam Research Centre, Vizhinjam 695 521, Kerala, India.
Email: 1612vv@gmail.com

Coris formosa is a species of wrasse in the second largest marine fish family, Labridae, native to the Indian Ocean from the Red Sea and the coast of Africa to Sri Lanka. This family contains more than 65 genera and 460 species. This Formosa wrasse is a moderately hardy fish. Their amazing coloration, active presence in the water column and peculiar swimming style makes them one of the favourites fish in aquariums and they are known for their striking colours and patterns. The majority of Coris species remain in small harems consisting of a single large adult male and several smaller juvenile and female fish.The juvenile and adult appearances of Formosa Wrasse vary greatly. In order to study the change in colour pattern, 20 juvenile specimens of this species were collected and stocked in a 1000 litre glass aquarium with a 10 cm layer of coral sand substratum over a under gravel filter in which they can bury themselves. A canister filter was also provided as additional filtration support. Water quality parameters; salinity ranged from 28-32 ppt and pH 8.1-8.3 and temperature 28-31ºC.They were fed on a varied diet consisting of mussel meat, *Artemia*, mysid and pellets.

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It has been observed that Formosa wrasse juvenile (15 mm-60 mm) has a body colour of orange with white tiger stripes across the back. The stripes and fins are outlined in black and the body weight ranged from 2-7g and at this stage the fish was non aggressive. By the time it attained a length of 60-70mm, the wrasse started changing its body pattern and behaviour. The first prominent change recorded was a raw of black spots which appeared at the base of anal fin and then the black spots spread over its body in parallel rows. It took 6-7 months for the wrasse to develop into a fully black spotted Queen coris and their length ranged from 120-150mm. The next change was a prominent blue diagonal stripe across the orange face of the fish which was observed at a length of 150mm onwards. During this period they were always seen hiding behind the rocks or sand beds and slowly the white tiger stripes also started disappearing. As an adult, the females displayed a dark blue green body with black spots, accented by red on the fins, and a light-blue diagonal stripe across the orange face and the males showed a light-blue body with vertical blue stripes and several green stripes on the face at a length range of 160 mm-180 mm. The transformation from the juvenile to adult occurs within a period of 12-15 months.

MECOS 2 |APSP 19

Growth of *Dunaliella salina* under different salinity ranges

Suja, C. P. * and K. Alfred Dhas
Central Marine Fisheries Research Institute, Tuticorin Research Centre, Tuticorin 628 001, Tamil Nadu, India
Email: cpsuja@gmail.com

The aim of the present study was to find out the maximum growth of *Dunaliella salina* a halotolerant unicellular organism in laboratory conditions. The strain of *Dunaliella* maintained in the stock culture laboratory of Tuticorin Research Centre of CMFRI, using Walne's medium as nutrient source was used for this experiment. The experiment was maintained at room temperature 23°C, pH 7.4 and light intensity 1000 lux with a photoperiod of 24:0 (light: dark). This marine microalgae was examined for its growth under five different salinity concentrations of 10ppt, 20ppt, 30ppt, 40ppt, and 50ppt. Cell density was assessed by counting the cells using a Haemocytometer on 8th, 16th and 24th day of inoculation of cells. Highest cell density was noted in 20ppt in all the three counts. On 24th day, the maximum number of cells, 40.2×10^4 cells/ml, and the lowest, 8.9×10^4 cells/ml, was recorded in the salinity of 20 and 10 ppt respectively. Growth rate was calculated and it was also high (0.183) in 20ppt and low (0.120) in 10 ppt. It was 0.15, 0.145 and 0.130 in the salinity of 30, 40 and 50ppt respectively. The result of the experiment suggest that 20ppt salinity is ideal for high cell density for stock culture maintenance in laboratory conditions and increase in salinity beyond 20ppt decreases cellular concentration.

Table: 1 Growth rate and Cell density under different salinity and different periods

Day	Number of cells (x104 cells/ml)				
	10ppt	20ppt	30ppt	40ppt	50ppt
8	3.0	8.0	4.7	4.1	2.8
16	4.2	13.8	10.9	7.9	5.1
24	8.9	40.2	18.4	16.4	14.3
Growth rate	0.120	0.183	0.150	0.145	0.130

MECOS 2 |APSP 20

Comparison of specific growth rate in cultch-less oyster spat and spat settled on ren from hatchery and wild: influence of ecological factors

Chinnadurai, S.*, V. Kripa, J. Sharma and K. S. Mohamed

Central Marine Fisheries Research Institute, Kochi 682 018, Kerala, India. Email: chinnaduraitvl@gmail.com

The edible oyster (*Crassostrea madrasensis*) is farmed by villagers in central Kerala and a value chain has been developed to increase the farmed oyster production and market. As a part of a world bank aided project (National Agricultural Innovation Project) production of cultch-less spat for developing single oysters was attempted at the Shellfish hatchery of CMFRI at Njarakkal, Kerala. The edible oyster pediveliger larvae were made to set on conditioned polythene sheets and simultaneously another set of spat were set on empty oyster shells. The cultch-less spat were then reared in the hatchery upto thumb–nail size and then transferred to cages suspended from wooden rack farms in Vembanad Lake at Moothakunnam, Sathar Island. The spat settled on rens in hatchery and spat collected on rens from the natural bed were also stocked in same farm and their growth was monitored. The specific growth rate (SGR) of same cohort oyster spat in two different cultch materials, and influence of varying ecological parameters were studied. The growth of the oyster spat depends on several seasonal, climatic and ecological factors. Based on this background one year sampling of oyster spat growth of varying cultch materials was done from January 2012 to December 2012. The temperature, salinity, pH, ammonia, nitrite, nitrate, phosphate, DO, BOD, TSS, POM, and PIM of the shellfish growing water were studied. ANOVA shows no significant ($p > 0.05$) variation in the growth of the oyster spat on various cultch materials. The Pearson correlation revealed the temperature and chlorophyll were positively correlated ($p < 0.05$) with spat settled on polythene sheet. Similarly spat settled on ren in hatchery was also positively correlated ($p < 0.05$) with total suspended solids (TSS), particulate inorganic materials (PIM). On the contrary, the wild settled spat were not significantly correlated ($p > 0.05$) with any ecological parameters. The study indicates that once the spat from different origin are placed in shellfish growing waters, there is no difference in their growth.

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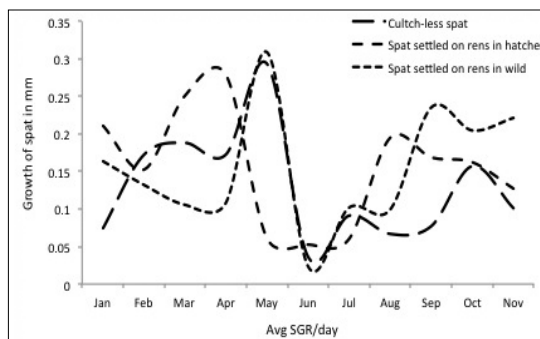
Fig. 1. Monthly average specific growth rate (SGR) of spat settled on polythene sheet, rens in hatchery and spat collected on rens from the natural bed.

MECOS 2 |APSP 21

New technology for induced gamete maturation as tools in broodstock development and spawning of *Lutjanus argentimaculatus* in open sea cage

Madhu, K.*, Rema Madhu, T. Retheesh, T. Tinto, K. M. Venugopalan and M.P. Mohandas
Central Marine Fisheries Research Institute, Kochi 682 018, Kerala, India. Email: kmadhu30@rediffmail.com

The mangrove red snapper *Lutjanus argentimaculatus* belonging to the family Lutjanidae is one of the important candidate species in aquaculture as it can survive in freshwater, brackish and saltwater (inshore and offshore) habitats and grow up to a length of 104 cm with weight 14.5 kg . Apart from this, its popularity as a food fish and high market value contributed to substantial interest for capture based aquaculture in the recent past in India. However its culture is mainly dependent on wild collected seeds. The Gonadosomatic Index (GSI) and the peak reproduc-tive activity exhibited two peaks (September and October; February and March) in an year. Considering the importance of this species in cage culture, initiatives were taken in CMFRI, for its broodstock development in the open sea cages. The brood fishes reared in the circular cage of 6 m diameter were tagged with 12.8mm PIT tag for identification and monitoring the developmental stages of each fish.

The fishes were fed twice daily at 0900 and 1530 hrs with sardines, stolephores, squid and mussel meat @ 5% body weight. Vitamin and mineral supplements were also given twice a week. Cannulation were carried out once in a month initially and later at every 15 and 7 days interval to track the ovarian developments. Cannulation of reared live fishes showed that most of the specimens are male and the females had developed gonads with ova size ranged between 100 to 200 micron. In order to speed up the ova maturation, after ensuring gonadal state,

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50, 75 and 100μg of GnRH for female and half of these concentration for male fishes were intramuscularly administered. The fishes without GnRH administration were treated as control. The fishes administered 75μg GnRH showed significantly higher percentage of oocyte developments. The study showed that after three months administration of GnRH, the ova reached 340 to 420 micron. In order to conduct breeding trial, female fish having ova diameter 540-580 micron and ripe males were transported to hatchery, and were administered Human Chorionic Gonadotropin (HCG) at the rate 1000, 1500, 2000 IU/kg a for females in two split doses and half of these concentration for males. The hormone injected fishes (1500 IU/kg) spawned successfully in the hatchery and the spawning occurred (24 hours after injection) at early morning on April 30th 2014. The newly spawned eggs were 800 to 900 micron size with single oil globule having 150 to 160micron diameter. This is the first work on captive hormone induced spawning of *L. argentimaculatus* in India.

Ammonia oxidizing archaea in a zero water exchange shrimp culture system: Analyses based on functional gene amoA coding ammonia monoxygense

Ramya R. Nair*, I. S. Bright Singh and Valsamma Joseph
National Centre for Aquatic Animal Health, Cochin University of Science and Technology,Lakeside Campus, Kochi 682 016, Kerala, India. Email: ramyavellur@gmail.com.

Zero water exchange shrimp aquaculture systems are environmentally sustainable and biosecured systems for large scale production of disease free and healthy shrimps. A stable environmental quality was observed in such systems managed with an indigenous bioaugmentor developed by National Centre for Aquatic Animal Health, Cochin University of Science and Technology. These systems were reported to sustain disease free animals and stable environmental quality throughout the culture period. The ammonia generated from feed and the metabolic wastes from the cultured animals could be always maintained at optimal or below detectable levels indicating active nitrification and diverse nitrifying communities in these systems. Nitrification is a two-step process where ammonia is converted to nitrite and then to nitrate. There are increasing evidences that ammonia oxidizing archaea play equally important roles as that of bacteria in global nitrogen biogeochemical cycling. Since nitrifying organisms are slow growing and unculturable, a metagenomic approach was followed in the present study to understand the diversity of ammonia oxidizing archaeal communities in a zero water exchange shrimp culture system.

The water and sediment samples were collected from a zero water exchange shrimp culture system located in Kerala, India before stocking the ponds with animals and at the end of the culture period just before the harvest of animals (120th day). This was done for the evaluation of the shifts in archaeal communities, the redox potential and the concentrations of ammonia, nitrite and nitrate. The concentrations of ammonia, nitrite and nitrate were maintained below 0.1 mg/l

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at the beginning and end of the culture period and the redox potential could be maintained above -150 mv even on the 120th day of culture. These results indicated that the environmental quality could be maintained with the applied bioremediation protocol and there is active nitrification in the system with diverse nitrifying microbial communities. For the metagenomic analyses of ammonia oxidizing archaeal communities, the metagneomic DNA was isolated using Power soil DNA isolation kit (MoBio Laboratories Inc., USA) and archaeal *amo*A gene encoding the α-subunit of the ammonia monooxygenase enzyme was amplified using specific primers. Sequence based functional gene libraries of archaeal *amo*A were constructed and the diversity was compared at the beginning and end of the culture period. The phylogenetic analyses of the clones showed maximum similarity to Crenarchaeotal *amo*A genes. The clones at the beginning of the culture showed 98% similarity to archaeal *amo*A genes from diverse environments such as mangrove sediments, estuarine sediments and aquaculture farms. The archaeal *amo*A clones from the pond sediment at the 120th day of culture showed 98% similarity to archaeal *amo*A genes from mangrove sediments as well as from nitrifying bioreactors and municipal waste treatment plants. There was an increase in overall diversity of the ammonia oxidizing archaeal communities towards the end of the culture indicating that more the culture system is loaded in terms of biomass and generated wastes, the stability of the system is maintained by more diverse archaea along with other microbial communities present. The roles of various microbial communities in maintaining the environmental stability, especially the ammonia and nitrite concentrations, in zero water exchange shrimp culture systems needs to be studied in detail for the development of appropriate bioremediation strategies.

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Migration of Hilsa shad (*Tenualosa ilisha*) in relation to sea surface salinity and wind direction - A case study in northern Bay of Bengal near West Bengal coast

Sandip Giri
School of Oceanographic Studies, Jadavpur University, 188, Kolkata 700 032, West Bengal, India.
Email: sandip2012ju@gmail.com

Migration of Hilsa shad (*Tenualosa ilisha*) is a very well-known phenomenon in the Indo-Gangetic and Brahmaputra river basin. It has a wide range of distribution in marine, estuarine and riverine systems. Study on factors that influence the migration of Hilsa is very much important for further research on forecasting of Hilsa catch. In this study, attempt has been made to observe, how Hilsa migrates in response to the change of sea surface salinity and wind direction.

Salinity is an important parameter as Hilsa migrates upstream towards lower salinity for spawning and larval rearing and while doing so, they are caught in estuarine areas. In this project sea surface salinity and wind vector data have been

recorded throughout the year 2013-14 (except during fishing ban period in West Bengal coast). Hilsa catch locations have been collected from ten GPS controlled fishing boats, with the gill net. This fish catch positions have been plotted over the interpolated sea surface salinity and wind vector mapsandocean state forecast map provided by Indian National Centre for Ocean Information Services. It was found that, Hilsa starts migrating from salinity around 35 ppt and maximum brood fishes are caught from the near shore where salinity is around 15 ppt. Moreover, the boats which operated the nets against the wind direction (driven by both easterly trade winds and south-west monsoon winds) caught more fishes compared to those which operated their nets arbitrarily irrespective of the wind direction.

MECOS 2 |APSP 24

Hatchery runts show initial upsurge in growouts in the Blacklip pearl oyster *Pinctada margaritifera* in Andaman & Nicobar islands

Linoy Libini, C.*, K. A. Albert Idu, C.C. Manjumol, V. Kripa and K.S. Mohamed
Central Marine Fisheries Research Institute, Blacklip Pearl Oyster Laboratory, Port Blair 744 101, Andaman and Nicobar Islands, India. Email: linoylibini@gmail.com

Comparative studies were made on growth and survival of the hatchery raised blacklip pearl oyster *Pinctada margaritifera* spat of the same cohort in different stocking densities, depths and weaning methods in sea farming. Initially, all spat showed more growth which is evident in the respective IGR values irrespective of their stocking densities and weaning depths. But the growth rate was comparatively more in runts which decreased drastically after 60 DOC. The growth and survival rates decreased with increasing DOC and stocking densities. But both are not influenced by the depth of the culture zone. No mortality of spat was noticed in low stocking density (SD-10) during the period of experiment. In SD-20, some mortality was noticed in higher depth zones (6 and 8 m) only in the end phase which may due to low water currents with high silt load. But, in SD-30, a gradual increase in spat mortality was noticed from 30 DOC onwards. The highest cumulative mortality (52 %) was observed in the high density stocks (runts) maintained in surface floating barrels with horizontal and vertical flow systems with periodic de-fouling and thorough cleaning (Fig 1). However, the mortality rate was low (15-18 %) during initial days up to 90 DOC (summer months) and then drastically increased to 36 - 45 % with the onset of monsoon.

Spats which were weaned on spat settlers with protective webbing showed high size variations and with 50% cumulative mortality due to the heavy fouling intensity on the settlers. Complete mortality was observed within 100 DOC in settlers without protective webbing due to high predation. Major predators were fishes belong to the families Gobidae, Siganidae, Balisitdae, Tetradontidae, Lethridae, Serranidae and Parrot fishes along with invertebrates like *Cymatium cingculatam*, crabs and sea urchins. The intensity of foulers such as ascidians, encrusting sponges, polychaetes, seeds of different organisms such as shrimps,

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bivalves and gastropods on spat and collectors also hinder the spat growth. These foulers obstruct the entry of seawater carrying food particles and attract other predators. This is the major setback in weaning spat on collectors and transferring them as such from the settlement tanks in the hatchery (Fig.2).

Hatchery runts showed shooting growth during the initial days. While comparing IGR values, the runts maintained with vertically upward water flow (FB-Ver) showed better performances than that with horizontal water flow (FB-Hor). The intensity of sudden spurt in growth is directly dependent on the size of the transplanted spat and it was found to be reduced when the size of the spat increased. The IGR values for runts were much higher than that of the normal spat weaned even in low densities (SD-10, 20 and 30). These observations reveal that the runts showed a good growth in the initial month itself and are capable of achieving growth similar to normal spat, when provided with favourable conditions and effective management.

Furthermore, spat grown in low densities (SD - 10 and 20) grew faster and almost attained the same size as the shooters within the experiment period of 210 DOC. Temperature greatly influenced spat growth. The growth and mortality was also influenced by the intensity of rainfall and the water currents along with total suspended sediment in the culture site. Results indicate that the growing area and its environment variability strongly influence growth than their genetic factors.
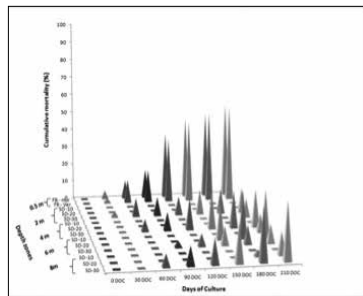
Fig. 1 Cumulative mortality percent of spat in different stocking densities at various depths
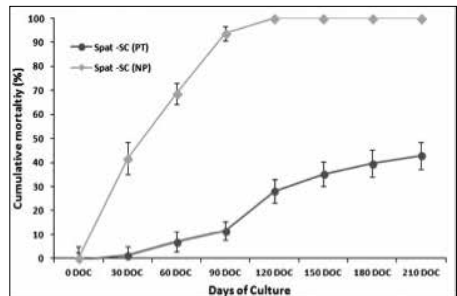
Fig. 2 Predatory mortality of spat weaned in spat settlers with and without protective webbing

MECOS 2 |APSP 25

Analysis of gonadal biopsies, hormonal induction and spawning in Cobia *Rachycentron canadum*

Gopakumar, G.*, A. K. Abdul Nazar, R. Jayakumar, G. Tamilmani, M. Sakthivel, A.K. Samal, P. Rameshkumar, V. A. Maharshi, S. Sirajudeen and R. Thiagu
Central Marine Fisheries Research Institute, Mandapam Regional Centre, Mandapam Camp 623 520, Tamil Nadu, India. Email: drggopakumar@gmail.com

Cobia aquaculture is gaining momentum globally and in India successful cobia breeding and seed production was achieved in 2010. When held in captivity, cobia exhibits reproductive dysfunctions and natural spawning in captivity is rare.

Administration of exogenous hormones is essential for obtaining the final oocyte maturation and spawning. The induction of spawning with exogenous hormones like human chorionic gonadotropin (hCG) was carried out after the assessment of reproductive maturity through gonadal biopsy. The female spawners were considered sexually mature when the oocytes had diameter of more than 700 μ. The dosage of hCG was 500 IU per kg body weight for females and 250 IU per kg body weight for males. Out of 31 spawning experiments conducted, 61.3 per cent yielded fertilized eggs, 29.0 per cent yielded unfertilized eggs and 9.7 per cent did not spawn at all. Several factors like maturation stages of ova, condition of males, temperature and physiological state of the brooders affect the success of spawning. In this study, an analysis was made by relating the maturation stage of the ova, temperature and success in spawning. It was found that spawning success was significantly higher when induction was made with the percentage of matured ova diameter was at least 25 percent andthe water temperature range was between 27.5 and 29.5ºC.

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Growth performance of GIFT tilapia in a brackishwater cage at Cochin, Kerala, India

Imelda Joseph*, C. N. Sarimol and Boby Ignatius
Central Marine Fisheries Research Institute, Kochi 682 018, Kerala, India. Email: imeldajoseph@gmail.com

Cage culture is widely used in fish production in most parts of the world. Tilapias are farmed in more than 85 countries and they have many desirable qualities like high stocking density, resistance to diseases, omnivorous feeding habit etc. Genetically Improved Farmed Tilapia (GIFT) developed by the World Fish Centre, has captured considerable percentage in the markets in Philippines, Thailand and Vietnam.The Central Marine Fisheries Research Institute (CMFRI) has developed the technology of cost effective cage aquaculture in the country and the demonstrations in public-private partnership (PPP) mode have enhanced the visibility of the technology in almost all the maritime states in the country.

The cage culture of GIFT tilapia was conducted at Cochin as a farming option during south-west monsoon season in Kerala when the traditional shrimp farms remain flooded due to heavy freshwater influx. The farming was done on participatory mode with major inputs like seed and feed from the farmer. During the five months (including nursery phase), the fish were able to tolerate 0 to 17 ppt salinity without affecting growth performance. During June 2013 GIFT seed measuring <5 cm on an average, procured from Rajiv Gandhi Centre for Aquaculture (RGCA) were reared for two months in a closed nursery pond of about 435 sq.ft. After attaining 25-35 g, 1500 fish were transferred to a steel square cage measuring 4 m x 4 m. Due to biosecurity concerns, the cage was installed in the sluice pit of the registered pond at a depth of 3.75 m by fixing bamboo poles at four corners. The net depth was 3.5 m and the mesh size ranged from 16-40 mm depending on fish size. A high density polyethylene pipe (HDPE) filled with weight was inserted inside the inner net and was tied to the poles for keeping the net shape intact.

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The fish were fed with 2 mm commercial floating pellets of 32% crude protein @ 5% body weight during the first month in the cage and later with 4 mm pellets of 24% protein at the same rate. As a supplement, duck weed and Azolla were also provided on alternate days (5-8 kg/ day). After three months of grow-out period in the cage, the weight ranged between 400-600 g with an average weight of 450 g. On harvest about 600 kg of fish were caught. The survival rate obtained was 96%. The price realized at farm gate was Rs.200/kg. The flesh quality based on report of a taste panel (public of different categories) was found to be superior with appealing flavor and fat content. This has more emphasized because tilapias are not a favoured fish in Kerala due to its regular low flesh quality. About 600 kg (Rs.34/kg) feed was used and the FCR was1:1. It was observed that GIFT tilapia is a good option for farming during monsoon season under fresh to low saline (0-15 ppt) conditions. Economic evaluation during first crop has worked out an operating ratio of 0.826, which would be about 0.360 for subsequent crops since the cage frame as well as nets could be reused further. The success of the pioneer attempt by CMFRI has attracted many entrepreneurs into cage culture of GIFT tilapia in Kerala and has been found very lucrative and optional in monsoon flooded traditional farms.

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MECOS 2 |APSP 27

Captive breeding technology of marine ornamentals: Prominent emerging opportunity, a successful story from Lakshadweep Archipelago, India

Sibi T. Baby*, M. Gopi, Sherine Sonia Cubelio and M. Sudhakar
Centre for Marine Living Resources and Ecology, Field Research Station, Agatti, U. T. of Lakshadweep, India.
Email: sibitbaby88@gmail.com

The island groups of Lakshadweep have unique coral reef ecosystem with high biological diversity. Among the 300 species of ornamental fishes reported from Lakshadweep are known for their aesthetic, ecological, economic and cultural functions. Among them, clowns and damsels which are widely used as marine ornamentals belongs to a diverse and well distributed family Pomacentridae. The sub adults of clown fishes at different size groups and the sea anemones were collected from the island waters adopting eco-friendly methods and were introduced into the conditioning tanks. After two months of rearing period, pair formation occurred. One pair growing ahead of others became the spawning pair and the same was removed along with the host anemone and introduced in to the spawning tank. Ceramic tiles, dead coral pieces, live rocks etc were provided as spawning substratum. The fishes started spawning after three months of rearing and continuous spawning was achieved.

Spawning activities included chasing and extended fin movement. When spawning was about to occur, the male chased the female to the nest. The female made several passes over the nest and eventually laid orange colour eggs over the period of more than 45 minutes. The male then continued the process as he passed over

the eggs and fertilizing them. Once the spawning was complete, male took the responsibility of guarding the eggs, where the female acted as a supervisor of the male. Eggs were 2 - 2.2mm in length, 1 - 1.2 mm in widths and capsule shaped. The number of eggs at a single spawning varied from 400 – 700.

The photoperiod was maintained as 13/hr/light: 11 hrs dark by using 25 W fluorescent bulbs. The fishes and anemones were fed with tuna egg mass, boiled clam meat, trash fish, squid and octopus thrice a day at 5% of the body weight. Incubation period varied between 6 to 7 days and the tank water temperature influenced the development of eggs. The eggs underwent several distinct color changes as they developed. The deep orange color eggs gradually changed to brown, turning blackish and finally to silver prior to hatching. The water quality parameters were maintained as 28 - 30°C (temperature), 30 - 32 psu (salinity), 8.2 - 8.4 (pH) and 5 - 6 ml/l (D.O.). Ammonia, nitrite and bacterial load were maintained at permissible levels and were critically monitored at regular intervals.

After the completion of 30 days larval rearing, metamorphosis occurred in the entire batch of larvae and the same were shifted and stocked in 500 litre capacity FRP tanks stocked with an anemone. The physico-chemical parameters excluding light were maintained as same as parent tank. The young ones were fed with boiled minced mussel and fresh fish flesh. Micro algae such as *Chlorella* spp.,*Nanochloropsis* spp., *Isochrysis* spp. and rotifer, *Brachionus plicatilis* were developed as stock culture in a separate live feed culture room. Chlorinated seawater was used for the production of algal mass culture. After adding the algal inoculam, on the third day when the algal cell density reached the appropriate level, rotifers were inoculated at the rate of 18 nos. /ml. Rotifers multiplied rapidly by feeding the algal cells and within 3-5 days, the culture attained maximum concentration of 50 - 100nos. /ml. Harvesting of rotifers was done with a hand net of 50 *μ*m mesh size and washed thoroughly with fresh seawater and fed to the newly hatched larvae.

Thus maintenance of good quality water, sufficient quantity and timing of feeding to the fishes especially in larval period, regular checking of water quality parameters and health of fishes result a successful saga of captive breeding and rearing of marine ornamentals.
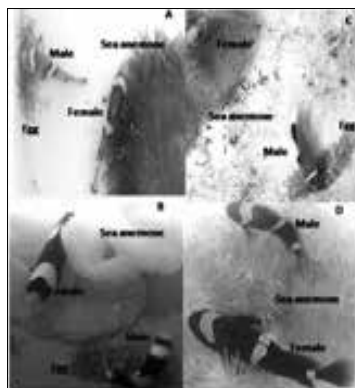
Fig.1. Clown fish brooders having with egg, *Amphiprion percula* (A); *A. clarkii* (B); *A. nigripes* (C); *Premnas biaculateus* (D)
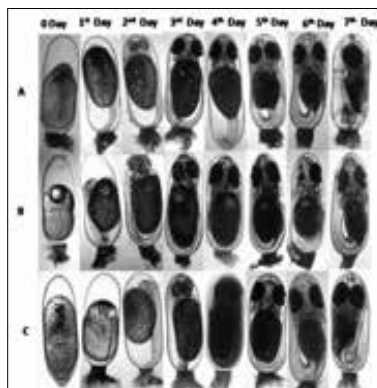
Fig.2. Embryonic development of *Amphiprion nigripes* (A); *A. percula* (B); *A. clarkii* (C)

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Carbon fractions dynamics and accumulation in shrimp culture ponds - potential for sequestration

Muralidhar, M.*, R. Saraswathy, M. Vasanth, P. Kumarraja, N. Lalitha, V. Chitra and A. Nagavel
Central Institute of Brackishwater Aquaculture, 75, Santhome High Road, Chennai 600 028, Tamil Nadu, India. Email: muralichintu@ciba.res.in,

Aquaculture ponds accumulate a lot of carbon in their sediment and water column. During the shrimp production cycle, considerable quantity of organic and inorganic waste accumulates in the pond, depending upon the intensity of culture practices. In order to understand the carbon dynamics, inorganic and organic carbon contents of pond bottom soil and water column were estimated in *L. vannamei* (Nagapattinam and Kalpakkam) and *P. monodon* (Nagapattinam and Mahabalipuram) culture farms with different stocking densities of 40 to 45 and 9 to 11 nos./m¬2 respectively. These fractions were also evaluated over a period of eight crops for four years from 2010 to 2013 at Nagapatinam to assess the accumulation of total carbon in shrimp culture pond soil. The water and soil samples were collected after pond preparation (before stocking), once in a month during culture period and after the harvest from all the study sites and transported to the laboratory in ice cool box for immediate analysis. The organic, inorganic and total carbon load in the water samples were determined by using Shimadzu TOC-Vcpn analyser, while that of soil were quantified by Shimadzu TOC-Vcph analyzer with SSM-5000A unit.

The organic carbon content in the pond bottom soil of *L.vannamei* culture ponds (0.51 to 2.26 %) was more than that of *P.monodon* culture ponds (0.32 to 1.48%), whereas no significant difference was observed for inorganic carbon content between *L.vannamei* (0.05 to 0.48%) and *P.monodon* culture ponds (0.06% to 0. 48%). The clay content of the pond bottom soil exhibits greater affinity for binding the organic carbon than inorganic carbon, irrespective of the species cultured. A reverse trend was observed with respect to these fractions in the water column i.e., inorganic carbon content was high in *L.vannamei* culture ponds (26 to 43 mg/l) compared to *P.monodon* culture ponds (9 to 24 mg/l) and not much difference for organic carbon content between *L.vannamei* (3 to 9 mg/l) and *P.monodon* culture ponds (4 to 11 mg/l). The accumulation of organic and inorganic carbon contents at the pond bottom soil showed an increasing trend owing to the quantity of inputs being greater with an increase in the stocking density of the culture species and the days of culture, whereas no particular trend was observed with these fractions in the water column.

Studies on carbon accumulation revealed no significant difference with respect to the total carbon content of pond soil after pond preparation over a period of four years, though a slight increase was observed at the end of four years period (Fig.1). The pond preparation practices like proper drying, tilling and application of lime materials might have helped in decreasing the accumulated carbon status of soil

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after harvest of every crop. An amount of 2.4 tons of carbon/ha was sequestered over a period of four years due to the increase in soil carbon status. However, the carbon content in harvested pond soils was high and this can be sequestered by making use of the sediment as an alternate source of manure through composting or biochar preparation processes. Carbon sequestered in aquaculture farms could be used as carbon reduction credits against the farm's carbon emissions.

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Reproduction, early development and larviculture of *Amphiprion frenatus*

Madhu, K.*, Rema Madhu, T. Retheesh, T. Tinto, M. P. Mohandas and B. Binoy
Central Marine Fisheries Research Institute, Kochi 682 018, Kerala, India.
Email: kmadhu30@rediffmail.com

Amphiprion frenatus is a clown fish of ecological importance and of importance in the aquarium trade. This study describes the reproductive behaviour, the embryonic, larval developments and the general breeding and rearing conditions. Ten sub adults reared for pair formation became breeding pairs within 3-5 months after acclimation under captivity. The fishes were fed twice daily with wet feeds such as meat of shrimp, mussel and clam at the rate of 10% of their body weight and live feeds like *Brachionus plicatilis* and newly hatched *Artemia nauplii*. The environmental parameters were maintained at optimum level i.e., temperature 27 to 29 °C, salinity 32 to 34 ppt, dissolved oxygen 4.6 to 6.2 ml/l and pH 8.1 to 8.4. On the day of spawning, both the parents spent considerable time for the cleaning the site which indicated that spawning may occur within few hours. Spawning was noticed between 0600 hrs and 1530 hrs during day time and the spawning lasted for one to one and a half hours. In each spawning, 200 to 600 capsule shaped eggs having size 1.2 to 3.0 mm in length with a width of 0.8 to 1 mm were laid at an interval of 15 to 30 days. During incubation period, both the parents carefully looked after the eggs during day time. The peak hatching took place after sunset between 1830 and 1930 hrs at a water temperature range of 27 - 29 °C. The newly hatched larvae measured 1.5 - 3.5 mm in length, and the mouth gape of the newly hatched larvae ranged from 300 to 365 μ. In order to find out suitable live feed for the growth and survival of larvae, different combination of live micro zooplanktons along with microalgae were carried out, and the larval rearing protocol standardized.

Effect of stocking size on the growth performance of rock lobster *Panulirus polyphagus* in open sea cages at NW coast of India

Divu, D.*, Mohammed Koya, Gyan Ranjan Dash, Sreenath K R, Vinay Kumar Vase, Swati Priyenka Sen Dash, Suresh Kumar Mojjada, Mahendrakumar Fofandi
Central Marine Fisheries Research Institute, Veraval Regional Centre, Veraval, Gujarat 362 269, India.
Email: divudamodar@gmail.com

Rock lobster *Panulirus polyphagus* were reared at four different stocking sizes in the open sea cages of north-west coast of India to evaluate the effects of stocking size on growth performance. Lobsters with various size groups (i.e. 60-80g, 80-100g, 100-120g and 120-140g) were stocked in similar stocking densities with triplicates. The initial stocking weight (±s.e.) were 63.88 ± 0.22, 81.85 ± 0.35, 114.50 ± 2.89 and 128.72 ± 3.06, respectively. The growth trial lasted for 90 days from Decemebr 2013 to February 2014. Individual weights of lobsters in each cage were recorded in fortnightly intervals. The final mean weights (±s.e.) of the lobsters stocked at various sizes reached 146.35 ± 2.54, 182.80 ± 6.12, 177.25 ± 0.49 and 189.49 ± 4.24g respectively. The final body total length and weight though significantly lower in smallest size group (60-80g), the growth rate was significantly higher compared to the higher size groups i.e. 100-120g and 120-140g. However, the highest final body length and weight were noticed when the lobsters were stocked at a size group of 80-120g or higher. The final body total length and weight though significantly higher in 80-100g compared to 60-80g, the growth performance i.e. WG% and SGR was statistically not found to be significantly different at temperatures ranging between 22 and 27°C and salinity of 32-38 ppt. In all the experiments survival rate was >93%. Therefore, lobster seeds should preferably be stocked at 80-100g size to maximize yield while maintaining the growth performance.

Dominance of *Rhizosolenia* in Palk Bay: Does *Kappaphycus alvarezii* cultivation play any role ?

Temkar Ganesh, Subir Kumar Mandal*, N. Monisha, J. Malarvizi, G. Ajay, R. Jenifer
Marine Algae Research Station (CSIR-CSMCRI), Mandapam Camp 623 519, Tamil Nadu, India.
Email: mandal@csmcri.org

Due to increasing atmospheric greenhouse gases, global average temperature is being increased by ~0.2°C per decade. The global average sea surface temperature have already been elevated 0.58°C above the average global temperature, recorded

for the 20th century. Marine phytoplankton is well known as the key component of the marine pelagic ecosystem and is generally influenced by global climatic conditions as a whole.The climatic conditions of the south Palk Bay, south east India and the spatial distribution,community composition and species succession of marine phytoplankton populations in this region are studied more than a decade. Monthly average of daily high air temeprature was increased @ 0.21 °C / 5 yrs for the last 15 years, whereas monthly average of daily low temperature was decreased @ 0.03°C / 5 yrs for the similar period in the Palk Bay region.Average maximum wind speed (June, July and August) was also slightly increased every year. For example, three months average of daily wind speed was found to be 11.94 (1997), 12.73 (2002), 12.87 (2008), 12.93 (2011), 13.70 (2012) and 12.70 km/h (2013).

The recorded precipitation was also increased with time. During 2002, there was no record of rain during June to August months. Recently (2013), the recorded precipitation was 36.2 mm, which was highest among all the last 5 years i.e. 10.2 mm in 2011 and 9.0 mm in 2008. Along with the changing climatic conditions, the seaweed cultivation activity such as *Kappaphycus alvarezii* (a carragenophyte) was also increased in the Palk Bay region. It was initiated with a yield of 21 MT (dry wt.) during the year 2001 to 1450 MT (dry wt.) in 2013. The impact of climate change and cultivation activities in this region on marine phytoplankton community has been doccumented in the present communication. In the year 2002, *Chaetoceros* was dominant (28.34%) in this region, whereas *Rhizosolenia* was found to be dominant (89.06%) in August 2008 and reached to 99.29% in August 2011.

Correlation between average daily high air temperature and phytoplankton total count (TC) as well as *Rhizosolenia* count showed strong positive correlation (r^2=0.85 and r^2=0.92) respectively. Average maximum wind speed showed similar trend with total count ($r2$=0.85) as well as with *Rhizosolenia* (r^2=0.89).On the other hand, the average precipitation for the respective months and total count of marine phytoplankton as well as *Rhizosolenia* showed negative correlation (r^2= -0.88 and r^2=-0.92) respectively. It was noticed that the total count of marine phytoplankton reduced as *Kappaphycus* cultivation was increased during 2008 (888 MT) and beyond i.e. 2013 (1450 MT). During 2013, there was an outbreak in the *Kappaphycus* cultivation, which again reduced density of *Rhizosolenia* in this region. It is interestingly found that the contribution of *Rhizosolenia* within marine phytoplankton community, was 99.29 %during 2011 and become dominant in Palk Bay region. The dominace of *Rhizosolenia* may be due to combined effect of climate change and *Kappaphycus* cultivation.
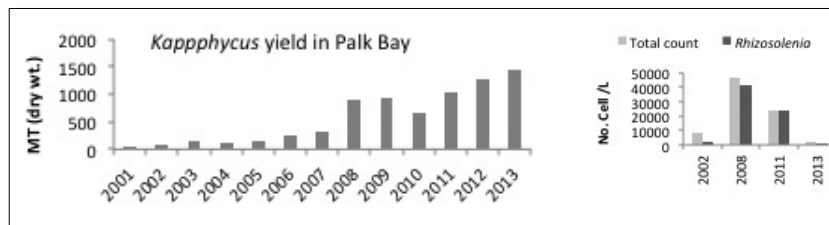
Fig. 1: A) *Kappaphycus* yield in MT (dry wt.) and B) Phytoplankton count in Palk Bay region.
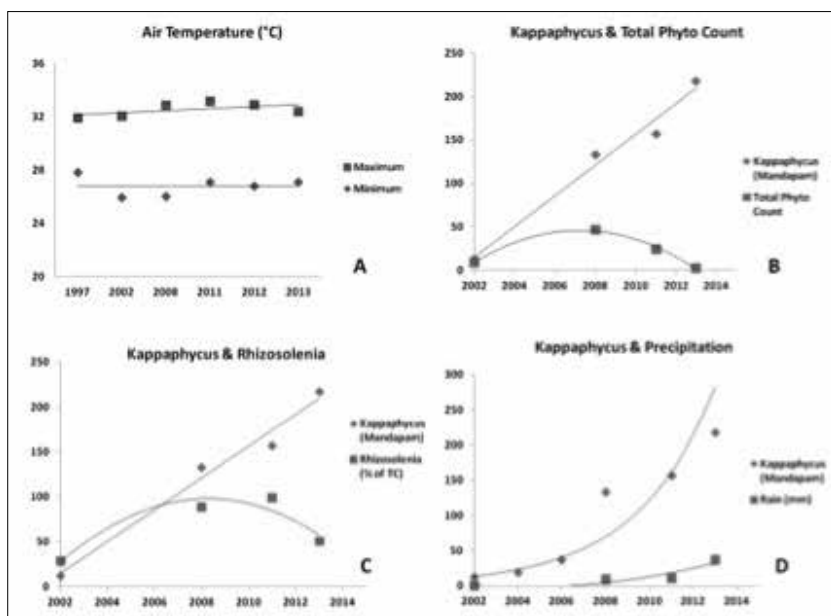
Fig 2: A) Average daily (August only) high and low air temeprature in Mandapam area. B) *Kappaphycus* production in MT (dry wt.) in Mandapam and total phytoplankton count (No. X103 /L) C) *Kappaphycus* production in MT (dry wt.) in Mandapam and *Rhizosolenia* sp. % of dominance within total phytoplankton count. D) *Kappaphycus* production in MT (dry wt.) and Precipitation (mm) in Mandapam region.

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MECOS 2 |APSP 32

Effect of minerals on shell hardening of Mud crab *Scylla serrata* (Forskal, 1775)

Kurkute, S. L., A. S. Pawase*, D. I. Pathan, H. T. Dhaker and M. S. Sawant
College of Fisheries, Ratnagiri-415 629, Maharashtra, India. Email: anilpawase@yahoo.com

Assessment of preliminary and optimum requirements of minerals in shell hardening of mud crab, *Scylla serrata* was carried out during the present study. Juveniles of live mud crabs in the size range of 73 to 94 mm carapace width and weight range of 110-160 g were stocked in HDPE circular tanks of 125 l capacity. The experiments were carried out according to the completely randomized design. The pre-moult crabs were subjected to various concentrations of minerals such as $CaCO_3$ and KCl (each @500 to 1100 mg. l^{-1} at the interval of 100 mg. l^{-1}) and $MgSO_4$ (1400 to 2000 mg. l^{-1}). Duration of hardening period was counted on daily basis after moulting. On the basis of the results, it was observed that post moulted or soft crabs could be hardening at relatively shorter duration of up to 9 ± 0.58 days when reared in the water having salinity of 23-28 ppt with mineral contents of 800mg. l^{-1} each of $CaCO_3$ and KCl and 1700 mg. l^{-1} of $MgSO_4$. The details are discussed in the paper.

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Cage culture of cobia (*Rachycentron canadum*) in brackishwater areas

Boby Ignatius*, Shoji Joseph, Imelda Joseph and K. M. Venugopalan
Central Marine Fisheries Research Institute, Kochi 682 018, Kerala, India. Email: bobycmfri@gmail.com

The rapid growth rate in farming conditions, as well as the high quality flesh, makes cobia (*Rachycentron canadum*) one of the preferred finfish species in mariculture production. Apart from marine cages, Cobia is amenable to rearing in ponds, net–pens and recirculation aquaculture system. This species is first farmed commercially in Taiwan during early 1990s and since then the farming of cobia has expanded extensively to various parts of the world and aquaculture production of cobia increased nearly 7000 fold between 1995 and 2005. The large scale interest on the cobia farming is mainly because of the high growth shown by the fish in farming conditions, with fishes reaching 6 - 10 kg in 12 months of rearing.

The suitability of this fish for farming in the brackish water environment was studied. Culture of cobia was conducted in a floating cage (4X4x3m) moored at brackish water areas of perumon, Kollam. The cage was constructed using GI pipes of 1.5inch diameter. The net bags consisted of an inner net bag made with twisted HDPE (1.25mm) and outer protection net (HDPE net). The depth of net cage bag was 3m, which gives an effective volume of 48m^3. The net bags were tied to the GI frame and moored in the culture site using anchor, poles and PE ropes.

Juveniles of cobia having an average size of 19.2 cm (average wt.:31.66g), from marine finfish hatchery of CMFRI Mandapam, was stocked in the cage for farming. The stocking density was 4.0/m3. The salinity at the farming site during the start of farming operations was 25 ppt. After proper acclimatization, fishes were initially reared in hapas kept in the cages for close observation. After one week of rearing in hapas, the fishes were released into cage. Feeding was done with trash fishes collected from the local fishermen engaged in fishing that area. Feed was given ad *libtum*, three times a day by broadcasting from the sides of the cages. After 3 months of rearing, pellet feed procured from commercial feed supplier (Uni president feeds) was given to the fishes by replacing 50% of the trash fishes. Cages were checked periodically for damages and clogging of nets and repairs were done as and when required. Net exchange was practiced periodically and the size of the meshes was increased as per fish growth. Initially the inner net was of mesh size 14mm which was increased 18mm, 22mm etc. as fish grew. The water quality parameters of the culture site and growth of the fishes were recorded periodically. Fishes were harvested after a culture period of 5months. During this period fishes were grown to a size range of 1200 - 2220g (Aver. length: 49.4cm) with a survival rate of 82%. The harvested fishes were marketed locally at an average price of Rs.350/kg. During the culture period the due to the monsoon rains, salinity at culture site was dropped to less than 10 ppt in some occasions, but did not affect the growth and survival of the fishes in cages. The monthly growth pattern, SGR and other water quality parameters are presented in the paper.

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Vast Brackishwater areas in Kerala can be utilized effectively for the farming of fishes in cages. Successful cage farming trials conducted by CMFRI with various finfish species in brackish water areas in Kerala highlights the suitability of this culture method for increasing the fish production from state. The growth obtained from the present study is comparable with the growth obtained elsewhere in cage farming of cobia. The high growth rate of cobia makes it a potential species for farming in low saline areas of the state. Eight months farming season between September-October to April-May months is ideal for farming cobia in brackish water areas of Kerala. During this period, there will not be much reduction in salinity of water and an eight month culture of cobia in cages can yield fishes of average weight 3.0-5.0 kg, a size preferred in market. Partial replacement of trash fish with pellet feeds after initial growth phase is found to be a suitable feeding strategy for reducing the dependency on trash fishes for rearing these fishes in captivity.

Marine Biodiversity, Climate Change & Ecosystem Assessment

Track 3

Biodiesel production potential of the haptophyte microalga *Prymnesium parvum* isolated from Cochin Estuary

Sanyo Sabu*, I. S. Bright Singh and Valsamma Joseph
National Centre for Aquatic Animal Health, Cochin University of Science and Technology, Lakeside Campus, Kochi 682 016, Kerala, India. Email: sanyosabu@yahoo.com

Microalgae represent an extremely diverse and highly specialized group of micro-organisms that live in diverse ecological habitats with a wide range of environmental conditions and are being very well exploited for the production of variety of compounds of biotechnological interest. But there is a great necessity of selection of new autochthonous strains of microalgae with high growth rate and capability for simultaneous production of several valuable compounds along with biodiesel. In the present study, we analyzed the potential of *Prymnesium parvum*, a haptophyta microalga belonging to Prymnesiophyceae, isolated from the Cochin estuary, India for the production of third generation biofuels.

Prymnesium sp. MACC15 (KJ845343) was isolated from brackish water of Cochin estuary near Mattanchery Harbour (9°56′47″N, 76°15′52″E) using nutrient enriched sea water media F/2 at 25°C with a photoperiod of 16:8 light and dark under 2500 lux. An individual *P. Parvum* cell with an ellipsoid or narrowly oval cell shape has two equal flagella and a well developed haptonema. Molecular identification using 18S ribosomal ribonucleic acid (rRNA) gene and 28S rRNA gene large subunit (LSU) specific primers respectively gave high percentage sequence similarities with published sequences of *Prymnesium parvum* CCAP 946/6 (96%) and *Prymnesium parvum* strain RCC1435 (97%).

The growth studies based on absorbance at 750 nm and dry biomass weight showed that the species had an exponential phase up to 15-16 days with a dry biomass of 8 mg\100ml on 20th day of culture. Nile Red staining for *in-situ* determination of lipid bodies showed the presence of yellow fluorescent lipid bodies against red background. Nile Red fluorescence assay showed that the neutral lipid content increased with the days of culture and was the highest towards nutrient deprived stationary phase. The biochemical composition of *P. Parvum* on 20th day of culture showed 40.28% protein, 21.67% lipid and 6.78% carbohydrate of the total dry weight. The fatty acid profiling using gas chromatography mass spectrometry (GC-MS) showed the characteristic of good quality biodiesel with saturated fatty acid-myristic acid (20%), and monounsaturated fatty acids- palmitoleic (56.7%) and oleic (6.7%) acids and no polyunsaturated fatty acids. The biodiesel properties such as octane number (48.14) and iodine value (100.88 g I2100g-1fat) were within the range of ASTM D6751-02 standards for biodiesel. With further augmentation of lipid production and improvement of fatty acid profile through biochemical, genetic and metabolic engineering approaches and screening for potential by-products, *Prymnesium parvum* could be a potent candidate for biofuel production.

Differential gene expression under acidic stress from an acid tolerant euryhaline microalga, *Dictyosphaerium ehrenbergianum* : Strategy of organisms towards ocean acidification

Subin, C. S. *, M. A. Pradeep and K. K. Vijayan

Central Marine Fisheries Research Institute, Kochi 682 018, Kerala, India. Email: cs.subin08@gmail.com

Ocean acidification is one of the major consequences of global warming which seriously damage the marine organisms. Oceanic pH decreased to 0.1 U due to the industrial revolution in the eighteenth century and it is further estimated to decrease 0.5 U and reaches around a pH of 7.7 by 2100.The tolerance level for acidic environment is varied from organism to organism and some algae have the ability to tolerate pH 3 or even below. A decreased pH reduce the photosynthetic efficiency of phytoplankton and thereby reduction in the ocean productivity is anticipated. Nutrition to coral reefs is mainly contributed by the symbiotically associated microalgae and decreased ocean pH seriously affects symbiotically associated algae which would be one of the reasons for phenomena such as coral bleaching. In the present study we have isolated euryhaline microalgae, *Dictyosphaerium ehrenbergianum* (CMFRI-MBTD-S129) which has the ability to tolerate wide range of salinity from 0‰ to 40‰ and also the saline acclimatized cells which have the ability to tolerate acidic environment up to pH 3. Multiple stresses enhance the expression of various genes to overcome these stressful environments

This study was aimed to elucidate the effect of acidic pH on the acid tolerant microalgae, *D. ehrenbergianum* at molecular level. *D. ehrenbergianum* was isolated from the Cochin estuary during the rainy season (July) when the salinity was very low (2ppt). The cultured alga was subjected to different stresses and only saline acclimatized (35ppt) cells tolerated acidic pH. Suppressive Subtractive Hybridization (SSH) technique was adopted to characterize the differentially expressed genes under acidic pH. Algal cells grown under acidic condition (pH 4) were used as tester and cells at normal condition (pH 8) were used as driver. A total of 200 transcripts represented differentially expressed genes under acidic stress. All the identified genes directly or indirectly involved in the acid or abiotic stress tolerance mechanisms and are actively involved in biological process of the cell.Among the gene fragments analysed 55% showed sequence similarity with functional genes, 21% unknown genes which may have functional roles in abiotic stress and the remaining 24% contributed ribosomal genes. Functional genes are classified based on their function such as photosynthesis, cell proliferation and DNA repair, metabolic processes, stress response, cellular transport of ions (Fig.1). Some of the differentially expressed gene fragments were further validated quantitatively using Real-Time PCR to confirm the reliability of SSH. Quantitative validation showed that the selected genes have upward regulation under acidic stress (Fig.2). Some of the important functional genes differentially expressed under acidic stress include H+ATP synthase, major-facilitator-like ion transporter, thioredoxin, calmodulin, osmotically inducible protein, glutathione peroxidise and

cinnamyl alcohol dehydrogenase etc. with significant role in abiotic stress tolerance. Further characterization of these genes revealed the molecular mechanisms actively involved to mitigate the acidic stress. These genes from extremophilic organism would enable the genetic modification of ecologically sensitive and economically important organisms to sustain varying climatic conditions.
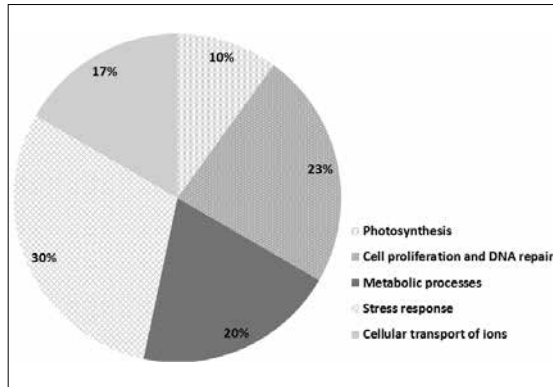
Fig. 1 Functional classification of differentially expressed genes under acidic stress.
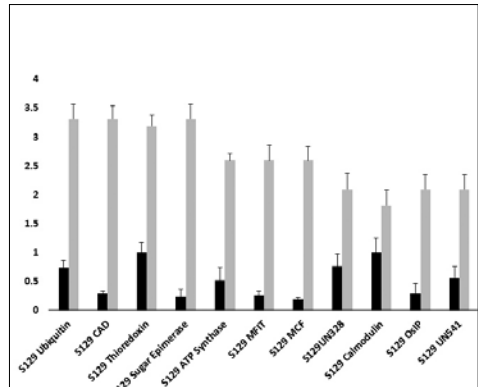
Fig. 2. Quantitative validation of differentially expressed gene fragments using Real-Time PCR

MECOS 2 | MCEO 03

Spatial shifts in abundance of small pelagic along Indian coast: have we examined the available information before relating to climate change?

Vijayakumaran, K
Central Marine Fisheries Research Institute, Madras Research Centre, 75, Santhome High Road, Chennai 600 028, Tamil Nadu, India. Email: vijayettan@yahoo.com

The climate change related research had gained a foothold in most research organizations with significant funding from various sources. In an attempt to deliver notable outputs, researchers often exhibit a tendency to relate the phenomena under observation to climate related variables ignoring other factors that might have played a significant role. This paper examines how the proposition that shift in distribution of small pelagics due to climate change got elevated to become conventional wisdom, defying logical thinking process of science.

The current knowledge that the small pelagics have moved north along the coast due to the change in SST regime is reexamined in the light of new and old published information which probably did not get the required weightage. Examining the records of distribution, the behavior of fish, the changes in fishery and trade and market for fishery products, an attempt is made to establish that the several other factors could have played a dominant role in the abundance in space of the small

pelagic rather than climate related factors as is currently believed.

The paper argues that primarily fishery has to be considered as function of fishing effort and the effort partially a function of market demand. The paper suggests that 'fishing down the food-web' in combination with the change in fishery could be more reasonable factor than climate change for the wider spatial abundance of small pelagic in recent times. Cautioning the researchers against the temptations of jumping the bandwagon by delivering output with sensational reference points that could satisfy the vested expectations, the author advocates for critical examination and open debates on the findings from different angles.

MECOS 2 |MCEO 04

Biotic assemblage on coastal defense structures: A contributor to biodiversity

Prince Prakash Jeba Kumar, J.*, G. Nandagopal and R. Rajan Babu
National Institute of Ocean Technology, Pallikaranai, Chennai 600 100, Tamil Nadu, india.
Email: prince@niot.res.in

Naturally dynamic, erosive and depositional soft-shores in the Indian shoreline have transformed into artificially static, hard-substrates by the proliferation of coastal defense structures in recent past. Those structures were colonized by organisms such as algae and sessile marine invertebrates that are native to natural rocky habitats as well as providing refuges and nursery grounds for fish and crustaceans. But the biotic assemblages that developed on a submerged hard substrate (breakwater) and on nearby coastal natural rocky substrate was different from the sand-filled geo-textile containers as a consequence of the physical properties of the substratum affecting organism recruitment. Through literature, it has been found that little attention has been paid to the harboring of epibiota on man-made coastal defense structures until the last decade and this study explores the nature of faunal assemblage on coastal erosion protection structures. The biotic community structural studies of macro faunal assemblage on geotube deployed at Kovalam coast reveals around 13 species of epibiota dominated by brown mussel recruitment. The traditional coastal defense structures like rock boulders, tetrapod and caissons located along Chennai coast recorded 12 species broadly categorized as macro-algae, bivalves and gastropods. The diversity pattern of epibiota population density has been studied using β diversity. The gastropod and bivalve population recorded high β diversity indicating the low similarity among the species with high population diversity along the various coastal defense structures studied. Whereas, the macro algae recorded low β diversity indicating the high similarity of species in the population with low diversity. Thus, epibiotic recruitment on coastal defense structures ultimately contribute to coastal biodiversity, the magnitude of contribution being in the order of Gastropod > Bivalve > Macro algae.

Diversity and distribution of Opisthobranchs and Polyclads in India with special reference to Andaman and Nicobar Islands

Raghunathan, C.*, Sudhanshu Dixit and K. Venkataraman
Zoological Survey of India, Andaman and Nicobar Regional Centre, Port Bliar 744 102, Anadman & Nicobar Islands, India. Email: raghuksc@rediffmail.com

The Opisthobranchs are group of marine gastropods which have an external shell, internal shell or entirely lack a shell as adults. Commonly called as sea slugs, these animals are known for their striking colour pattern and extraordinary forms. Opisthobranchs are among the least studied group of molluscs in India. Worldwide about 3500 species are described till date while in India only 311 species are known from 7 orders, 53 families and 141 genera. Among them, 194 species belongs to the order Nudibranchia which is the most diverse order. Besides, order Cephalaspidea consists of 54 species followed by order Sacoglossa with 37 species. Most of the studies on Indian opisthbranchs were conducted in Andhra Pradesh followed by Tamil Nadu, Gujarat, Andaman and Nicobar Islands and Lakshadweep. Periodic surveys conducted by Zoological Survey of India during the year 2008 to 2013 reported a total of 177 species of opisthobranchs belonging to 29 families and 70 genera till date from Andaman and Nicobar Islands. Of which Nancowry group of islands are the most diverse with 73 species followed by South Andaman with 71 species. Car Nicobar Island is least diverse as only 2 species reported so far.

Polyclads, commonly called as marine flatworms fall under order Polycladida of phylum Platyhelminthes. These worms are often mistaken as opisthobranchs due to their colour patterns. Polyclads are found in most marine habitats, usually on the sea floor among algae, corals, or on rocky reefs. Some have even been found at a depth of 2500m and are associated with the hot vent fauna in the Pacific Ocean. About 1500 species of polyclads estimated from world oceans. In India, Polyclads are also one of the lesser known marine animals as only 57 species are reported from Indian seas. Of which 22 species belonging to 3 families and 6 genera are distributed in Lakshadweep. The surveys conducted by Zoological Survey of India during the year 2008 to 2013 revealed out a total of 34 species under 3 families and 8 genera from Andaman and Nicobar Islands. Most of the species are recorded from South Andaman (14 species) followed by Great Nicobar Island (10 species). Intensive surveys in other reef areas of India may find more number of species including new species from these two lesser known faunal groups.

Process studies on the summer monsoon upwelling system of the southeastern Arabian Sea with special reference to Kerala coast (8-13°N)

Smitha, B. R.*, V. N. Sanjeevan, R. Sajeev, C. Revichandran and M. Sudhakar

Centre for Marine Living Resources and Ecology, Kendriya Bhavan, Kakkanadu, Kochi 682 037, Kerala, India.
Email: smitha.br@gmail.com

Physical processes and associated biogeochemical respons e of the coastal upwelling system of the southeastern Arabian Sea is explained based on *in-situ*, satellite and climatological data sets for the period 2003-2009. Observations on the isothermal shift during 2004-'09 for different transects between 8.5-13°N shows Kochi (10°N) as the strong upwelling area followed by Kollam (9°N) and Kozhicode (11°N). With regard to forcing mechanism, when the process at south (Trivandrum-8.5°N) is purely wind driven, along 9-12°N, combined action of wind stress and remote forcing takes the role. North of 12°N, role of remote forcing is weak and offshore transport is confined very near to the coast. Local alongshore wind stress and west-ward propagating Rossby waves regulate the extent of offshore mass transport for the middle sector (9-12°N). While at north, multiple impact due to West India Coastal Current (WICC) is observed; one way it uplift the isotherms by exerting shore ward push in the subsurface and in another way, the same current which carries dense saline water from north limits the offshore mass transport. Analysis on the biological response and the biogeochemical impact based on Chla, PP and DO delineate near bottom OMZ, the shore ward extension of the oceanic OMZ, and the bottom suboxia/hypoxia in the shelf region. Intra-seasonal variability explained based on time series observations at two transects off Kollam (9°N) and Trivandrum (8.5°N) which are nearby, but of significantly different oceanographic characteristics. Wherein, temporal variations explain a lag of 4 days for the hike in primary production following upwelling.

Assessment of spatial extent of predicted inundation at Sunderban mangrove ecosystem due to sea level rise using Geo Spatial Techniques

Jayanthi, M.*, M. Muralidhar, S. Thirumurthy, G. Nagaraj, S. Gnanavel, A. Panigrahi, M. Kumaran and J. Ashok Kumar

Central Institute of Brackishwater Aquaculture, 75-Santhome high Road, Chennai 600 028, Tamil Nadu, India. Email: jayanthivenkat@ciba.res.in

Changing climate scenario will be a potential threat for coastal ecosystems in the low

lying coastal areas. It will play major role for coastal problems such as flooding and inundation and the effect will be severe when associated with storm surge. As per IPCC report 2013, it is expected that the rate of global mean sea level rise will exceed the rate observed during 1971-2010 during the 21st century due to increased global warming. Many of the world's coastal wetlands have suffered significant losses during this century. The Sunderban mangroves are the largest mangrove ecosystem in the world and support an exceptional biodiversity with a wide range of flora and fauna and provide coastal protection to millions of people in India and Bangladesh. This study presents an appraisal of the impacts of sea level rise (SLR) on the low lying areas in and around Sunderban ecosystem. Digital Elevation Model (DEM) derived from Shuttle Radar Topographic Mission (SRTM), IRS P6 LISS IV data with 5m resolution derived from NRSC, Department of Space, Government of India and Geographical Information System (GIS) techniques are used to identify and quantify the area of inundation. The total land area of 13,98,431 ha has been classified to agriculture, aquaculture, mangroves, sparse mangroves, mudflat and water bodies. The vulnerability assessment was calculated based on the projected SLR scenario of 0.5 m and 1m. The results demonstrated that the mangroves of 15484 ha and 21086 ha will be submerged due to SLR of 0.5 m and 1 m respectively. Site specific plans for the development of mangroves in the upward regions may help to keep up with the impact of SLR due to climate change.

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MECOS 2 |MCEO 08

Spatial variation of size fractionated chlorophyll *a* in coastal waters of south eastern Arabian Sea

Minu, P.*, V. P. Souda, U. Sumith, P. M. Ashraf, L. Edwin and B. Meenakumari
Central Institute of Fisheries Technology, Matsyapuri P.O., Kochi 682 029, Kerala, India.
Email: minoos29@yahoo.co.in

Phytoplankton size structure influences the underwater light field and determines the fate of carbon in a pelagic food chain. They are the result of success of certain community to survive and grow in an unstable environment controlled by varying physical and chemical characteristics. Hence it is very important to understand the community structure of phytoplankton size fractions. Spatial and vertical variations of size fractionated chlorophyll *a* concentration (chl *a*) were investigated at 8 stations from May 2013 to April 2014 in order to understand the relationship between environmental parameters and phytoplankton size distribution in coastal waters of south eastern Arabian Sea. The growth of different phytoplankton was mainly controlled by nutrient concentrations in the area. Increased silicate concentration influenced the growth of microphytoplankton while nanophytoplankton was increased by nitrate and phosphate concentration. High ammonium concentration enhanced the growth of picophytoplankton. The study also showed a clear variation from a dominant diatom to dinoflagellate and cyanophyte community. The study identified abundance of microphytoplankton around 10 m depth, nanophytoplankton in surface to 5 m depth and picophytoplankton in 10-20 m water column. The regression analysis between total chla concentration and sum

of chla concentration in different size fractions showed good agreement ($R^2 = 0.87$; N=81). Pre-showers and extended southwest monsoon along with variation in nutrient concentrations in the area during the study period are responsible for variation in size fractionated chlorophyll, absorption by phytoplankton and its numerical density. These data will provide an insight into the chemical factors that control the production cycle in this neritic system. General patterns in the size structure of the phytoplankton community can also be used in improving size fraction algorithms for various societal applications of remote sensing.

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MECOS 2 | MCEP 01

Occurrence of Diatom-Diazotrophic association in the coastal waters of South Andaman

Manjumol, C.C.*, C. Linoy Libini, K.A. Albert Idu, K.S. Mohamed and V. Kripa
Central Marine Fisheries Research Institute, Blacklip Pearl Oyster Laboratory, Fisheries Training Centre, Marine Hill, Port Blair 744 101, Andaman and Nicobar Islands, India.
Email: manjumolcc@rediffmail.com

The heterocystous cyanobacterium *Richelia intracellularis* Schmidt 1901 is well known for its capability to fix the atmospheric nitrogen in oligotrophic waters. During the identification of phytoplankton samples collected from Panighat, South Andaman, we observed a Diatom-Diazotroph Association (DDA). The identified diatoms were *Rhizosolenia hebetata, R. clevei, R. cylindrus, Hemiaulus membranaceus* and the heterocystous diazotroph cyanobacterium was *Richeliaintra cellularis* (Fig.1). Trichomes of *Richelia intracellularis* are solitary, short, 13-20 celled, straight or slightly arcuated, more or less cylindrical along the whole length, without sheaths or gelatinous envelopes. Heterocysts are more or less spherical and develop terminally on one or (later) on both ends; they are spherical, wider than vegetative cells (Table 1).

Table 1. Morphological features of *Richelia intracellularis* in different diatoms

Diatoms	Length (μm)	Diameter of heterocyst (in μm)	No. of trichomes	No.of vegetative cells	Shape of heterocyst
Rhizosolenia hebetata	40-52a	9-11a	2a	7-8a	spherical or oval
	22.2-29.5b	-	6b	14-23b	spherical
	40-71c	9-13c	2c	8-13c	spherical
Rhizosolenia clevi	52-54a	7-10	14	9-10	spherical
Rhizosolenia cylindrus	36-38a	8-10	2	5-6	spherical

a. Present study, b. Madhu *et.al* (2013), c. Padmakumar *et al.* (2010) c

The genus *Rhizosolenia* was represented by twelve species viz., *R. alata, R. delicatula, R. cylindrus, R. imbricata, R. hebetata, R. styliformis, R. stolterfothii, R. formosa, R. pseudocalcaravis, R. clevei. R. setigera,* and *R. robusta* with a density

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of 2,37,050 L^{-1}. Eventhough *R. imbricate* constituted 18.94 % of total population, no symbiosis was observed. The *R. hebetata-Richelia* symbiosis were observed with a density of 200 cells L^{-1}and without *Richelia* the cell density was 300 cells L^{-1}. The *R. hebetata* cells varied between 230-550 μm length with a diameter of 10-28 μm. Three trichomes were present in *Richelia*, one trichome at one end with 7-8 vegetative cells and another two trichome at another end with 4- 5 cells. The cells varied in their size with apical axis of 310- 550 μm in *R. clevei-Richeliaintra cellularis,*. The density of *R. clevei* was 200 cells L-1. The spherical heterocysts was orienting towards one end of the host cell. A third symbiosis was observed with *R. cylindrus-R. intracellularis*. The density of *R. cylindrus* with or without symbiosis, averaged 100 cells.l^{-1}. Two trichomes of *Richelia* were observed in *R. cylindrus*, with a spherical heterocyst. In all samples of *R. cylindrus-Richelia* associations, only two trichomes were noticed and it is located at one end. *Richelia-Hemiaulus membranaceus* symbiosis also were observed in this sample. Number of *Richelia* trichomes per diatom showed variation(Fig.2 & 3). Sea surface temperature and salinity was 28°C and 32 ppt respectively. The total density of phytoplankton community was 1,273,300 cells.l^{-1}.Phytoplankton community was mostly composed of diatoms (98.12%), blue green algae (0.56%), dinoflagellates (0.12%) and silicoflagellates (1.18%). In the present study it was observed that the number of trichomes of *Richelia* sp. and orientation of the heterocysts occurring in different hosts diatom species showed variations. Forming a symbiotic association might be considered as an ecological adaptation to life in the oligotrophic seas. This report is intended to establish further research in the role of DDA's in oligotrophic waters especially in Andaman waters.
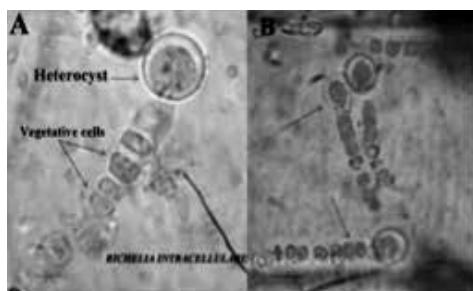
Fig. 1. (A- B) *Richelia intracellularis*
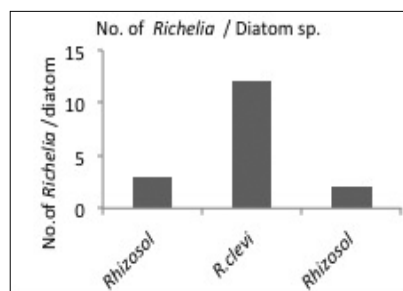
Fig. 2. Number of *Richelia* in different diatoms
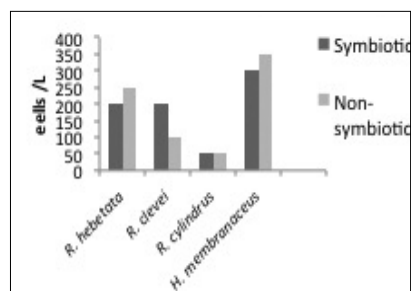
Fig. 3. Density of each species of diatom with or without *Richelia intracellularis*

Occurrence of red-tide of a ciliate in coastal waters of the Bay of Bengal, off Gopalpur, east coast of India

Biraja Kumar Sahu*and R. C. Panigrahy
Department of Marine Sciences, Berhampur University, Berhampur 760 007, Odisha, India.
Email: birajkumar@gmail.com

This paper deals with the occurrence of red-tide due to the blooming of the ciliate *Mesodinium rubrum* in coastal waters of the Bay of Bengal, off Gopalpur Port, Odisha. The morphological features, nutritional attribute, trophic relationship, global red-tide formation status and possible harmful effects of the bloom are also discussed. During routine environmental monitoring exercise, discrete red patches were observed in coastal waters of the Bay of Bengal, off Gopalpur Port on 24th April, 2014. The examination of live samples showed that this red-tide was caused by surface accumulation of the pigmented ciliate *Mesodinium rubrum*. This red tide was observed after the collapse of dinoflagellate *Noctiluca scintillans* bloom. Appearance of the present bloom suggests that environmental conditions became favourable in the coastal water for rapid growth of this ciliate to achieve its blooming status.

Mesodinium rubrum is a cosmopolitan species which often forms blooms in marine and estuarine environments. It is an obligate mixotroph that depends upon cryptophycean prey to carry out photosynthesis and sustain growth stealing its chromatophore. The species received greater attention when it was discovered that it has the ability to ingest cryptophytes and use their chromotaphore for carrying out photosynthetic function and its trophic link to the harmful bloom forming dinoflagellate, *Dinophysis* species. The other interesting features of this species are acquired phototrophy and karyoklepty in addition to its structural delicacy. These unique features and success in establishment of its stable culture lead to enumeration of its biotechnological applications.

Occurrence of algal bloom dominated by *Fragilariopsis oceanica* from the of southwest India

Abhijith, M.*, Anit M. Thomas, K.C. Vijayalakshmy, Akhil P. John, A.A. Mohamed Hatha and A.V. Saramma
Department of Marine Biology, Microbiology and Biochemistry, Cochin University of Science and Technology, Lakeside Campus, Kochi 682 016, Kerala, India. Email: abhijith86@gmail.com

West coast of India is highly vulnerable to algal blooms during the monsoon and post monsoon seasons as a result of seasonal upwelling and riverine discharge

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by monsoonal forcing leading to a nutrient enriched condition. Apart from this, a break in monsoon also provides a window for certain phytoplankton species to bloom because of favourable conditions arising out of a let-up in freshwater input into the sea. As part of the HAB monitoring programme of the Ministry of Earth Sciences, Government of India, sampling was carried out along the southwest coast of India during August 2013. On 14th August, a diatom bloom dominated by *Fragilariopsis oceanica* (Cleve) Hasle was observed off Kannur (Lat.12°00.24' N, Long. 75°13.28' E) . No water discolouration and foam formation were witnessed. The standing crop of the bloom was 10.3×107 cells L^{-1}, in which *Fragilariopsis oceanica* contributed 97% of the total microalgal biomass having a cell density of 10×107 cells L^{-1}. Other diatom species recorded from the bloom station were *Proboscia alata* (Brightwell) Sundström, *Coscinodiscus radiatus* Ehrenberg, *Trieres mobiliensis* (J.W. Bailey) Ashworth & Theriot, *Asterionellopsis glacialis* (Castracane) Round, *Thalassionema frauenfeldii* (Grunow) Tempère & Peragallo, *Skeletonema costatum* (Greville) Cleve, *Pleurosigma elongatum* W.Smith and potentially toxic diatom *Pseudo-nitzschia seriata* (Cleve) H. Peragallo along with dinoflagellate, *Pyrophacus horologium* Stein. The concentrations of nitrate, nitrite, silicate and phosphate were low ($0.23 \mu mL^{-1}$, $0.02 \mu mL^{-1}$, $0.56 \mu mL^{-1}$ and $0.13 \mu mL^{-1}$ respectively). The temperature was 240C, and pH was measured as 8.5. The salinity was 33psu which is favourable for the formation of the F. oceanic bloom. Dissolved oxygen concentration was moderate ($6.53 mlL^{-1}$).The relative composition of chlorophyll *a*, *b*, *c* and carotenoids were $12.3 mgL^{-1}$, $0.6 mgL^{-1}$, $2.6 mgL^{-1}$ and $6.1 mgL^{-1}$ respectively.

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MECOS 2 | MCEP 04

Distribution and abundance of harmful microalgae along the southwest coast of India

Vijayalakshmy, K. C. *, Anit M. Thomas, M. G Sanilkumar, A. A. Mohamed Hatha and A. V. Saramma
Department of Marine Biology, Microbiology and Biochemistry, Cochin University of Science and Technology, Lakeside Campus, Kochi 682 016, Kerala, India. Email: lakshmichandra86@gmail.com

A very small number of the several thousands of planktonic algal species known to exist in the ocean are potentially harmful. These can cause fish kills, contaminate seafood with toxins, pose a direct risk to human health, or otherwise affect the ecosystems harmfully. The increased recordings of HAB in coastal waters around the world have often been primarily associated with nutrients derived from anthropogenic activities. As one of the highest productive areas in the world, an understanding of the abundance and the distribution of the microalgae and its blooming especially in the coastal and estuarine stations along the southwest coast of India is quite significant. As part of this, regular monitoring was carried out at six coastal and estuarine stations during 2009-2011, from Azheekode (8°52'01"N & 76°34'26"E) to Thykadapuram (12°12'39"N& 75°07'33"E) by the HAB monitoring programme of the Ministry of Earth Sciences, Government of India.

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Diatoms were the dominant group in the entire study period except in the pre-monsoon of 2010-11, when a high cell abundance of harmful bloom-forming dinoflagellate *Tripos furca* (Ehrenberg) F. Gómez; was observed. Potentially toxic dinoflagellate *Dinophysis* sp. and *Alexandrium* sp., harmful bloom-forming *Prorocentrum lima* (Ehrenberg) F. Stein, *Prorocentrum micans* Ehrenberg and *Ceratium* sp. and bloom-forming diatoms like *Coscinodiscus* sp., *Odontella* sp., *Trieres* sp., *Asterionellopsis* sp., *Chaetoceros* sp., *Thalassiosira* sp., *Pleurosigma* sp. and *Proboscia* sp. were observed. Besides, toxic haptophycean *Prymnesium parvum* N. Carter and raphidophycean alga *Chattonella marina* (Subrahmanyan) Hara et Chihara were also recorded.

It is noted that blooming of algae would be possible in the optimal environmental conditions which include naturally driven physical forcing such as monsoonal influence, riverine discharge, seasonal upwelling and variations in temperature, salinity, irradiance, water stability and nutrient enriched waters. The abundance of microalgae and its blooming depend on multiple resources rather than on individual factors.

MECOS 2 |MCEP 05

Distribution of *Pyropia acanthophora* var. *robusta.* along the Indian waters

Veerendra Veer Singh*, Monica G. Kavale, Mudassar Kazi and Nived Sreenadhan
Central Marine Fisheries Research Institute, Mumbai Research Centre, 7 Bunglows, Versova, Mumbai 400 061, Maharashtra, India. Email: veerendraveersingh@gmail.com

Although intertidal rocks harbor abundant *Pyropia* on the Indian coast, the earlier studies were remained at low ebb for unknown reasons. Authors have documented *P. acanthophora* as a new report to Indian waters with its new variety *robusta*. The present study deals with systematics, distribution and ecology of *P. acanthophora* var. *robusta.* Biodiversity assessment revealed that *P. acanthophora* var. *robusta.* occurred only on central west coast of India during monsoon (June to September). Of the 45 sites visited along the west cost of India *P. acanthophora* var. *robusta.*was found growing only at 7 locations namely Vayangani, Redi, Malvan, Dona Paula, Cola, Kollam and Mullur. The present study thus deals with the characterization of *P. acanthophora* based on morphological and ecological diagnosis. The features selected for the morphological characterization are shape, size, texture and colour of plant, base of the blade, nature of the margins of the blade, thickness of the thallus, thickness of the mucilage, nature of perforations, diameter of monospores, diameter of vegetative and reproductive cells, distribution, division formula and number of fertile cells etc.

Vanishing seagrass meadows - Observation from four lagoons of Laccadive archipelago

Kaladharan, P.*, P. K. Asokan and A. Anasukoya
Central Marine Fisheries Research Institute, Kochi 682 018, Kerala, India. Email: kaladharanep@gmail.com

Seagrass meadows worldwide are disappearing fast, taking with them many species of finfishes, shellfishes, turtles, marine mammals and birds which depend on these underwater prairies as their habitat as well as feeding and breeding grounds. Regular monitoring on the biomass and density of seagrass vegetation in the reef and lagoons of Agatti (10° 52′ N & 72° 11′ E), Chetlat (11° 42′ N & 72° 42′ E), Kavaratti (10° 34′ N & 72° 39′ E) and Kiltan (11° 29′ N & 72° 50′ E) Islands of U.T. Lakshadweep since December 2011 indicated gradual but steady shrinking of seagrass meadows. The percentage reduction in seagrass meadows since December 2011 to August 2014 was estimated to 61% in Agatti, 77% in Chetlat, 35% in Kavaratti and 70% in Kiltan. Wet biomass of parts below the sediment (rhizomes and roots of seagrass) were always higher than (2.17 - 5.13 in Agatti, 2.84 - 5.49 in Chetlat, 2.45 - 4.36 in Kavaratti and 2.57 - 7.11 in Kiltan) the epigeal parts comprising leaves, stem and bracts. The possible reason behind this decline in seagrass biomass in the meadows may be complex and the principal ones among many others might be herbivory, deterioration of water quality due to increased anthropogenic activities and climate change. This situation calls for urgent steps to monitor the ecology and physicochemical parameters of water and sediment in the meadows while undertaking restoration programmes.

Seasonal variation of microzooplankton in Chilika Lake, a brackishwater lagoon on the east coast of India

Biraja Kumar Sahu*, S. Srichandan and R. C. Panigrahy
Department of Marine Sciences, Berhampur University, Berhampur 760 007, Odisha, India.
Email: birajkumar@gmail.com

Chilika (=Chilka) Lake is a shallow brackish water lagoon situated on the east coast of India. It covers an area of about 1020 km^2 in monsoon season that shrinks to 704 km^2 in summer. Hydrologically, it is influenced by three subsystems: (i) Mahanadi river system (ii) rivers and rivulets flowing into the lake from the western catchment and (iii) the Bay of Bengal. Seawater exchange between the lake and Bay of Bengal takes place predominantly through the outer channel that connects the lake with the sea and secondly via Palur canal that connects the southern

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sector of the lagoon (Rambha Bay) with Rushikulya estuary.

A study was carried out relating to abundance and composition of microzooplankton in Chilika Lake covering three seasons during 2012-13. Four groups such as the ciliates, rotifers, crustacean larvae and heterotrophic dinoflagellates constituted the major components. The relative contribution of each group remained disparate in different seasons. Ciliates however have emerged as the most dominant group throughout the lake in all the seasons except the freshwater dominant areas. The average contribution of ciliates however was highest (avg. 55.3±38.7%) in premonsoon season followed by post-monsoon (avg. 49.0±32.5%) and monsoon (avg. 47.8±41.6%) season. Crustacean larvae formed the second dominant group whose percentage contribution was marginally high in the premonsoon (avg. 41.2±38.8%) followed by monsoon (avg. 29.1±27.0%) and post-monsoon (avg. 28.7±23.4%) season. Results of cluster analysis and multidimensional scaling (using PRIMER) on abundance of microzooplankton depicted well defined clusters. Stations with higher salinity had more diverse groups forming different cluster indicating thereby that seasonal variation in species composition and abundance of microzooplankton is primarily governed by the salinity variations.

MECOS 2 |MCEP 08

Zooplankton abundance in Amini and Kadmat islands of Lakshadweep

Molly Varghese*, Rani Mary George, S. Jasmine, P. Laxmilatha, K. R. Sreenath, P. R. Behera, V. J. Thomas and J. Kingsley
Central Marine Fisheries Research Institute, Kochi 682 018, Kerala, India.
Email: mollykandathil@hotmail.com

Studies on zooplankters collected from the lagoons of Amini and Kadmatislands of Lakshadweep Archipelago were carried out based on a survey conducted during January - February, 2014. The displacement volume of zooplankton in Amini and Kadmat were 58.35 and 15 ml per 100 m^3 respectively. The density was also higher in Amini than in Kadmat which is estimated as 64480 and 47726 numbers per 100 m^3 respectively. A total of twentyone groups of zooplankters viz., copepods, crab larvae, ostracods, prawn larvae, chaetognaths, polychaete larvae, Lucifer spp., medusae, doliolids, mysids, tintinnids, molluscan larvae, euphausiids, appendicularians, siphonophores, cladocera, amphipods, squilla larvae, isopods, fish eggs and fish larvae were recorded from these two ecosystems. Groupwise studies indicated the dominance of copepods in Amini forming 40% while in Kadmat, the maximum was contributed by crab larvae(50%).The dominance of crab larvae in Kadmat was due to a swarm of zoea stage of crab in one of the stations. Among the copepods, calanoid copepods contributed the maximum with 71% in Amini and 81% in Kadmat. Followed by the dominance of copepods in Amini, ostracods(33%) and crab larvae(14%) formed major components. In Kadmat, copepods formed the second dominant group which contributed 20% followed by prawn larvae (11%), ostracods (6%) and the share by other groups were less than 5%.Comparative studies on the

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occurrence of different groups of zooplankters in these two ecosystems showed that copepods ando stracods were very much higher in Amini than in Kadmat while, crab larvae contributed more in Kadmat which was due to the swarming of zoea stage of crab. Both qualitative and quantitative abundance of zooplankters in these two ecosystems are presented and discussed.

MECOS 2 |MCEP 09

Benthic faunal diversity of Mahi River estuary, Gulf of Khambhat, Gujarat

Pandya, P. J. and K. D. Vachhrajani*
Department of Zoology, M. S. University of Baroda, Vadodara 390 002, Gujarat, India.
Email: kauresh@gmail.com

The Gulf of Khambhat, Gujarat, is peculiar for its geomorphology, hydrodynamics, high tidal amplitude (up to 12 m, second highest in the world) and high velocity of the entering tides. The gulf, being funnel shaped with wide mouth and narrow head provides geo assistance to tidal amplitude and turbulence. Prominent salinity and suspended solids gradation demark the estuarine gradient categorizing distinct microhabitats.

Benthic fauna are the vital component of the estuarine food chain and control the ecological functioning. The diurnal fluctuations and variations in abiotic conditions probably cause broad scale community pattern variations spatially and temporally. The sediment deposition, grain composition and variations on a diurnal, seasonal and annual basis define the micro habitat conditions. In an estuary, these variations are noted vertically, horizontally and laterally. Depending upon the length of the transitional zone from freshwater to salt water, the salinity gradient makes the conditions of an estuary moderate to harsh longitudinally. Tidal fluctuation and changes in water quality influence diversity and distribution of pelagic larval stages of benthic forms. Tidal variations induce site selection and abundance of benthic forms along the estuary. The estuaries of gulf of Khambhat are least explored for its faunal diversity and distribution. Therefore, present studies were carried out to enumerate the benthic faunal diversity of Mahi River estuary.

The estuarine stretch of Mahi river extends up to 50 km upstream (Valsad - 22° 26'N and 73°04'E) and opens into gulf of Khambhat at Kamboi (22°12 N and 72°36'E). Based on salinity gradation class, the estuary was divided into upper, middle and lower estuaries. The sites on both the south and north banks of Mahi estuary were considered for sampling during 2006 to 2012 (Fig.1). Each study site was divided into at least three sub sites owing to micro-habitat variations as well as habitat preferences of different fauna. The macrobenthic fauna was collected by hand picking method during field surveys. The sediments were passed through different mesh size sieves for the collection of microbenthic fauna. The core of one meter was drawn out, particularly in the lower estuarine mud flats, for microbenthic fauna and especially for the foraminifera. The collected specimens were washed with marine water at the site, narcotized and then preserved in 70% alcohol or 4% formalin till final preservation

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Fig. 1. Map showing the study area and study sites spread over the entire estuarine stretch of Mahi River. Panel on right shows representative fauna.

Category	Sub category		Identified species
Benthic microfauna	Foraminiferans		22
	Total		22
	Mollusca		24
	Annelida		02
	Arthropoda	Spider	01
		Crab	11
		Amphipod	01
		Isopod	01
		Barnacle	01
		Insect larvae	01
		Ant	01
	Chordata: Mudskipper		01
	Total		38
Associated fauna		Planktonic	60
	Avifauna		118
	Fishes		15
	Reptiles		01
	Mammals (Dolphin)		01
	Total		185
Grand Total			238

in absolute alcohol or 10% formalin. In the laboratory, the organisms were identified using illustrative and descriptive keys and the information available on various web sites. Since the morphological features are significant for identification, they were given prime importance for the confirmation of species identification. National and international experts were also consulted for authentication of identification. The specimens were then deposited in the Department of Zoology Museum and the details of collection and specimen were properly maintained.

Among benthic microfauna, foraminifera dominated with 22 species. The benthic macrofauna was dominated by 24 species of mollusc followed by 17 species of Arthropods. The molluscs were distributed in 13 genera and 10 families, where 16 species belonged to class Gastropoda and 8 species to class Bivalvia. Upstream (Vasad) showed maximum diversity with 14 species (52%) followed by Downstream (Kamboi) with 11 species (30%) and Midstream (Dabka) with only 5 species (18%). Diversity of associated fauna was also estimated which mainly included planktonic forms and avifauna. Comprehensive list of 238 species is prepared and their variation in distribution will be discussed.

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Swarming characteristics and diversity of scyphozoan jellyfishes along Mangalore coast

Saravanan, R.*, Mary K. Manisseri, Rani Mary George and K. K. Joshi
Central Marine Fisheries Research Institute, Mandapam Regional Centre, Mandapam Camp 623 520, Tamil Nadu, India. Email: raju.saravanan@cmfri.org.in

Eight surveys have been conducted for the collection, identification and quantification of jelly fishes in Netravati-Gurupur(9.8km^2) esturine system and one in Mulky-Sambavi (0.9km^2) estuary. In both the estuaries the jellyfish *Acromitus flagellates* swarming was recorded from 2009 until 2012. During the survey the individual jellyfishes weighing more than 2 kg were commonly recorded with the maximum bell diameter of 35cm. In 2010, the peak swarming of jellyfish was recorded in the month of November and the heavier blooms have occurred in high saline condition after south west monsoon. On the other hand the heavier monsoon in 2011 delayed the intrusion of saline water into the Netravati-Gurupur esturine system, hence the jellyfish swarming has been delayed by a month. This clearly indicates the prevailing salinity in the estuarine phase is an important factor in deciding the budding of polyp and subsequent swarming of medusae. Freshwater runoff in these rivers during summer months (November, December, January, February) is heavily reduced paving way for the saline water to intrude through the barmouth, which makes the riverine environment saline for several kilometers landward from the barmouth. This observation established the breeding site of this species, where recurrent medusae swarming have been observed year after year when favourable salinity condition exists. Jelly fish dynamics is important in the ecosystem functioning, as these predators actively influence the commercially important finfish fishery. The outbreak of jellyfishes in the ocean ecosystem around the World is attributed to climate change and other anthropogenic activities. Countries where the jellyfish epidemic has happened, there is an increased effort to assess them and manage them, through harvesting and scientific research.

Marine faunal biodiversity of the Nicobar group of Islands

Kiruba Sankar, R.*, Titus Immanuel, M. P. Goutham Bharathi and S. Dam Roy
Fisheries Science Division, Central Island Agricultural Research Institute, Port Blair 744 101, Andaman and Nicobar Islands, India. Email: rkirubasankar@gmail.com

Andaman and Nicobar Islands are remotely located islands of which Nicobar group of Islands remain still virtually untouched in terms of marine faunal biodiversity

cataloguing. Exploratory marine faunistic surveys have been carried out in three island groups of Nicobar viz., Nancowrie, Car Nicobar and Great Nicobar through rocky shore exploration in the intertidal and through SCUBA in the subtidal zones at 26 survey sites under 18 locations. A total of 318 species belonging to 10 phyla/ groups viz., fishes (157), mollusca (79), cnidaria (52), porifera (13), echinodermata (8), crustacea (5) and 1 each from annelida, polycladida, nemertia and urochordata were recorded and identified in the present study. Four opisthobranchs viz, *Phanerophthalmus smaragdinus* (Ruppell and Leuckart, 1828), *Dendrodoris nigra* (Stimpson, 1855), *Phyllidiopsis krempfi* Pruvot-Fol, 1957 and *Herviella mietta* Marcus & Burch, 1965 which are herein reported as new distributional records to Nicobar group of Islands. Inadequate marine faunistic exploration in the past could mainly be attributed to the geographical isolation of these Islands and lack of taxonomical expertise, which should be addressed in the future for precise biodiversity documentation.

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MECOS 2 |MCEP 12

Distribution and abundance of marine sponges based on depth in Andaman Islands

Kiruba Sankar, R.*, N. K. Chadha, S. Dam Roy, Paramita Banerjee Sawant, P. Neelam Saharan and P. Krishnan
Central Island Agricultural Research Institute, Port Blair 744 101, Andaman and Nicobar Islands. India.
Email: rkirubasankar@gmail.com

Marine sponges, one of the most abundant and diverse groups of marine benthic communities, form an important biotic component of the coral reef ecosystem in Andaman and Nicobar waters. Depth was identified as critical and influencing factor for sponge distribution and abundance. Influence of depth on sponge abundance and distribution was studied by quadrant method at selected sites in South Andaman (North Bay, Chidiyatapu, Havelock and Neil Island). At the selected study sites, 50 quadrants were placed randomly at depths of 0-5 m (shallow), 5-10 m (intermediate) and 10-15 m (deep) waters using snorkelling and SCUBA diving. The number of sponges encountered in each quadrant was recorded in every depth. In South Andaman, North Bay represented 17 species, Chidiyatapu 22 species, Havelock 26 species, and Neil Island 20 species in quadrants. Carteriospongia foliascens, Oceanapia sagittaria, Neopetrosia exigua are some of the frequently encountered species during the surveys. In this study, sponge density showed a significant ($p<0.05$) change at 5-10 m depth compared to 0-5 m and 10-15 m. In this study, North Bay was found to have maximum density of sponges (2.49 ± 0.22 nos./m^2) followed by Neil Island (2.2 ± 0.22), Havelock (1.91 ± 0.22) and Chidiyatapu (1.48 ± 0.22). Significant differences ($p<0.05$) were found in mean density of sponges at 5-10 m between sites, whereas in 0-5 and 10-15m depths, there was no significant differences ($p>0.05$) between the four sites. In case of Neil and Havelock, there was no significant differences ($p>0.05$) in mean density between the three depths whereas in case of North Bay and Chidiyatapu, there was significant differences ($p<0.05$) between three

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depths. Depth seems to be one of the most influencing factors for abundance of sponges in the present study. Studies on marine sponges are scanty owing to their complexity in taxonomic identification and difficulties in onsite identifications. The present study documented the distribution and abundance of sponges particularly depth wise in South Andaman waters.

MECOS 2 |MCEP 13

Diversity and distribution of Ascidians in south west coast of India

Abdul Jaffar Ali. H., V. Sivakumar, M. Tamilselvi, A. Soban Akram* and M. L. Kaleem Arshan
Department of Biotechnology, Islamiah College, Vaniyambadi 635 752, Tamil Nadu, India.
Email: akram.ascidian@gmail.com

In recent years, there has been growing awareness that ecological, economic and livelihood securities of mankind are inseparably linked with the conservation of biodiversity. This has resulted in renaissance of taxonomy to explore unidentified species and its distribution as well as abundance. The degree of ignorance is much greater with marine biodiversity and their importance for mankind rather than our knowledge of the biodiversity on land.

Ascidians belong to sub phylum Urochordata and contribute a major share in marine biodiversity. Besides, ascidians are a vast reservoir of bioactive molecules but we are only at a very elementary stage to understand diversity of ascidians. Though occurrence of ascidian fauna along the Gulf of Mannar region (south east coast) has been well studied, little is known from south west coast of India.

The present study reports diversity and distribution of ascidians along the south west coast of India fixing six different stations. A total of 42 species of ascidians belonging to 7 families and 19 genera were documented, four of which appear to be new records for India. Most of the species observed are recorded for the first time from the south west coast of India. Previous records of this species in India are from Gulf of Mannar particularly in Thoothukudi waters.

The family Didemnidae was represented by 13 species belonging to 4 genera, Styelidae by 11 species belonging to 7 genera, 8 species belonging to 2 genera from Polyclinidae, 5 species with 2 genera from Pyuridae, Polycitoridae and Perophoridae by 2 species each and Ascididae by 1 species.The present study showed that the diversity and distribution of ascidians have changed considerably when compared to a previous study. Diversity of ascidians in Vizhinjam Bay region was more than in the other region. As many as 28 species of ascidians were recorded in Vizhinjam bay, 16 species were recorded in Colachel, 6 from Kadiapattanam, 5 from Chinna Muttom and 4 each in Muttom and Leepuram.

The percentage composition observed among the various genera were

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Didemnum and Polyclinum17%; Microcosmus 10%; Botryllus and Trididemnum 7%; Botrylloides, Symplegma, Eudistoma and Diplosoma 5%; and Phallusia, Herdmania, Styela, Monandrocarpa, Polycarpa, Cnemidocarpa, Aplidium, Lissoclinum, Perophora and Ecteinascidia 2%.The results showed that distribution of colonial ascidians were found to be more in majority of the stations; whereas, the simple ascidians were restricted to port area only. The ascidian diversity and abundance of each station is reported in the present study.

MECOS 2 |MCEP 14

Community structure and spatial patterns in hard coral biodiversity of Lakshadweep Atolls, India

Sreenath, K. R., Rani Mary George*, S. Jasmine, V. Molly, P. Laxmilatha, L. Renjith, P. R. Behera and J. Kingsley
Central Marine Fisheries Research Institute, Vizhinjam Research Centre, Vizhinjam 695 521, Kerala, India.
Email: ranimary@yahoo.com

The Lakshadweep group of islands, off the west coast of India, constitute the only atoll reefs present under Indian Territory. It comprises 10 inhabited islands, 17 uninhabited islands, one with attached islets, four newly formed islets and five submerged reefs. These islands are located between latitudes 8°00' and 12°30' N and longitudes 71°00' and 74°00' E. A comparative study was conducted on selected islands of this reef to deduce the spatial patterns in hard coral biodiversity and community structure adopting the Line Transect Intercept Method. The islands studied were Agatti, Bangaram, Amini and Kadmat Island. The field work was carried out during January 2013 - March 2014. The study showed that *Acropora formosa* (Dana, 1846) formed the most prevailing species available in all the Islands. The highest and the lowest percentage of live coral cover were recorded at the reef flats of the Agatti (40.1%) and Amini islands (18.0%) respectively. Maximum similarity in species composition was found between Agatti and Bengaram island reefs. Mortality indices of all reefs classified them into the category "sick" and so further efforts should be focused on implementation of conservation strategies.

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Regular Echinoid diversity in Gulf of Mannar

Saravanan, R.*, P. Jawahar, T. Francis, B. Ahilan, R. Santhakumar and G. Gopakumar
Central Marine Fisheries Research Institute, Mandapam Regional Centre, Mandapam 623 520, Tamil Nadu, India. Email: raju.saravanan@cmfri.org.in

Gulf of Mannar, situated in the southeastern coast of India extending from Rameswaram in the north to Thoothukudi in the south along with its marine environment, has been declared in 1989 as India's first Marine Biosphere Reserve.

This region is blessed with 21 coral islands with rich coral reefs and associated faunal diversity. These islands are occurring in 4 groups namely Mandapam group, Kilakarai group, Vembar group and Tuticorin group. The Gulf of Mannar ecosystem comprises of three marine ecosystem viz., Coral reef ecosystem, Seagrass ecosystem and Mangrove ecosystem. Among these ecosystems echinoids are found in the former two ecosystems. With about 1,070 valid extant echinoid species known from the world oceans, sea urchins constitute a relatively small group compared to other echinoderms. The diversity of fossilised species vastly surpasses present sea urchin biodiversity, and more than 10,000 nominal species and 1,000 genera have been described. Traditionally, echinoids have been divided into two subgroups: regular echinoids, with nearly perfect pentameral (five-part) symmetry; and irregular echinoids with altered symmetry. Regular echinoids are benthic, epifaunal grazers using the Aristotle's lantern structure to feed on the macro algae and rhodolith beds. Regular sea urchins are coming under families viz., Cidaridae, Temnopleuridae, Toxopneustidae, Echinometridae,Echinothuriidae, Diadematidae and Stomopneustidae. Among the 264 species of echinoderms reported from Gulf of Mannar, regular echinoid diversity stands at 24. Many species of regular echinoids are ecologically importantant and they are cultured around the World for their 'roe' which is considered a delicacy in Japan and France. The present paper assess the regular echinoid diversity in the Gulf of Mannar which could form baseline data to assess their population size and reproductive cycle necessary for mariculture attempts.

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Status and conservation issues of window pane oyster *Placuna placenta* (Linnaeus 1758) in Kakinada Bay, Andhra Pradesh, India

Laxmilatha, P.
Central Marine Fisheries Research Institute, Kochi 682 018, Kerala, India. Email:laxmil@yahoo.com

The Kakinada Bay in Andhra Pradesh, India is a rich ground of the pearl bearing window pane oyster, *Placuna placenta*. The total landing of window pane oyster during 2011-2012 was 461.3 t; the total effort was 13,777 and mean catch per unit effort was (CPUE) 29.7 kg. The mean landing was 230.7 t and mean effort was 6,889. The window pane oyster is protected under Schedule IV of the Indian Wildlife Protection Act, 1972; however, clandestine fishing for live as well as fossilized shells of the window pane oyster occurs in the Kakinada Bay. This is highly detrimental to the stock of the window pane oysters in the Bay. The present status of the exploitation of the window pane oyster in the Kakinada Bay is assessed. The need to protect the species is highlighted and management and conservation measures are discussed.

Aggregation of beaked sea snake *Enhydrina schistosa* (Daudin, 1803) in mudbank area of southwest coast of India

Jeyabaskaran, R.*, K. S. Abhilash, Abbas A. Muhammed, Jishnu Mohan, P. G .Vishnu, L. R. Khambadkar and V. Kripa

Central Marine Fisheries Research Institute, Kochi 682 018, Kerala, India. Email: jbcmfri@gmail.com

The beaked sea snake *Enhydrina schistosa* (Daudin, 1803) is commonly found all along the Indian coast. There are about 22 species of sea snakes belonging to 3 families and 3 sub-families reported from Indian waters. All the sea snakes in India are protected under India Wildlife Protection Act 1972. During a special cruise onboard F.V. *Silver Pompano* for mudbank research, a shrimp trawl was operated in the near shore at 6 meter depth and inshore at 12 meter depth along Alappuzha coast. The beaked sea snakes were caught during each haul and immediately released into the sea in live condition. About 2 to 5 specimens regularly occurred in the catch at 12 meter depth in each haul and the number was always higher at 6 meter depth. The length of the specimens caught ranged between 51.7 and 112.6 cm. On 5th June, 2014 about 20 numbers of beaked sea snake were caught from the same location. The sea bottom was muddy and it was observed that the beaked sea snakes preferred to live in shallow muddy areas. The stranding of 4 to 6 dead beaked sea snakes were observed almost every day at Punnapara coast of Alappuzha, where the mudbank is formed during monsoon.

The food and feeding habits of beaked sea snakes was also studied based on the stomach content analysis. In the snakes caught from 6 meter depth, cat fish was the dominant food item while pufferfish were predominant in the snakes caught at 12 meter depth. The cat fish was identified as *Arius jella* and the puffer fish was *Lagocephalus inermis*. Occurrence of the school of *Arius jella* was common in mudbank area; hence the beaked sea snake abundance was more. The feeding behaviour of beaked sea snakes was also noticed. It was observed that they always ingest head portion of the prey first. The morphological features and biology of the beaked sea snake are discussed in the paper in detail.

First record of geographic sea hare, *Syphonota geographica*, Adams & Reeve, 1850, (Opisthobranch: Aplysiomorpha: Aplysiidae) in Pulicat Lake, east coast of India

Satyanarayan Sethi* and N. Rudramurthy
Central Marine Fisheries Research Institute, Madras Research Centre, 75, Santhome High Road, Chennai 600 028, Tamil Nadu, India. Email: sethisatyanarayana@yahoo.co.in

Geographic Sea Hare, *Syphonota geographica*, (Adams & Reeve, 1850) is a species of sea slug or sea hare and belongs to marine opisthobranch gastropod molluscs in the family Aplysiidae. It is distributed in Indo-West Pacific oceans, off Western Australia, the Mediterranean, and Red seas. This sea hare resides in lagoons, estuary and bays of sandy substrates. Specimens of geographic sea hare, *Syphonota geographica*, were collected from Pulicat Lake along East Coast of India. The density distribution of sea hare was minimum at a depth of 1 m and maximum of 10 cm (13°33'57"N 80°10'29"E) from sandy soil substrate. Sea hare are considered as a low value by-catch in India and hence discarded or used for manure and fish feed preparation. However, they are known to possess anti-cancer, anti-tumor and anti-viral compounds and therefore extensively used in the pharmacological industry in other parts of the world. A literature review on the distribution of this species revealed that this is the first report from Pulicat Lake along Bay of Bengal, East coast of India. Morphological features of this specimen is detailed in this paper.

On status review of crustacean fauna of Gujarat state, India

Saini, D. A , J. N. Trivedi*, R. Pareek , G. M. Soni, B. Purohit and K. D. Vachhrajani
Department of Zoology, M. S. University of Baroda, Vadodara, Gujarat, India. Email: djtrivedi4@gmail.com

Information on the status or occurrence of species in an area provides basic foundation for the construction of an effective conservation policy. Gujarat is a maritime state and the coast line of the state is longest in the country (1650 km). The coastal areas of the state are majorly divided into three regions viz. Gulf of Kachchh, Saurashtra coast and Gulf of Khambhat. The coastal areas of the state support different kinds of marine habitats which include 29 % of muddy flats followed by 28 % of sandy beaches, 22 % of marshy coast, and 21 % of rocky coast. The coastal areas of the state are very diverse in case of marine biota

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and studies on distribution and diversity of marine fauna have been carried out by different organizations and researchers. Out of various marine invertebrate fauna occurring on the Gujarat coast, only few groups have been studied in detail which includes mollusca and cnidaria but the crustacean fauna of the state is least studied or rather neglected.

The present study is carried out in two parts. In the first part, detail literature review regarding crustacean fauna of the state was carried out. The literature was reviewed in detail and checklist of crustacean species was prepared. The accepted scientific names of the species were adopted from WoRMS websites. In the second part, field surveys in the different coastal areas of the state were carried out. Specimens of various crustacean species were collected and identified up to species level using different identification keys. All the identified specimens were deposited into the zoology museum of Department of Zoology, Faculty of Science, The M. S. University of Baroda, Vadodara, Gujarat, India.

Total 147 species belonging to 80 genera and 39 families of crustaceans were reported from Gujarat state, which includes 1 species of isopod, 1 species of amphipod, 1 species of barnacle, 6 species of anomuran crabs, 104 species of brachyuran crabs, 31 species of shrimps and prawns and 2 species of lobsters and 01 species of stomatopods. Out of 147 species of crustacean species reported from Gujarat state, maximum species were reported from Gulf of Kachchh followed by Saurashtra coast and Gulf of Khambhat (Table 1). Gulf of Kachchh supports maximum diversity of crustaceans because of two reasons, firstly, out of 62 studies reported, maximum studies were carried out in Gulf of Kachchh and secondly, the area supports unique kind of marine habitat like coral reef which is not found in other coastal areas of state. The coastal areas of Saurashtra coast and Gulf of Khambhat support unique kind of crustacean diversity like *Macrophthalmus (Mareotis) laevis* A. Milne-Edwards, 1867 which was first time reported from India. Several other species of crustacean were also reported from Saurashtra coast and Gulf of Khmabhat which are not found in Gulf of Kachchh. It clearly implies that the area has excellent potential for biodiversty studies and must be explored meticulously to find the occurrence of crustacean fauna.

Table 1: Crustacean diversity of different regions of Gujarat state. IS: Isopods, AM: Amphipods, BA: Barnacles, AN: Anomuran crabs, BR: Brachyuran crabs, PS: Prawns and Shrimps, LB: Lobsters, ST: Stomatopods.

Region		Total	IS	AM	BA	AN	BR	PS	LB	ST
Gullf Of Kachchh	Species	128	1	0	1	6	97	20	2	1
	Genus	74	1	0	1	2	58	9	2	1
	Familly	36	1	0	1	2	24	5	2	1
Saurashtra coast	Species	73	0	1	1	6	36	27	2	0
	Genus	43	0	1	1	2	27	10	2	0
	Familly	25	0	1	1	2	15	4	2	0
Gulf of Khambhat	Species	37	0	0	1	1	24	11	0	0
	Genus	26	0	0	1	1	17	7	0	0
	Familly	17	0	0	1	1	12	3	0	0

Eco-biology of a precambrian intertidal benthic brachiopod, *Linguala anatina* from the confluence of Subarnarekha estuary with Bay of Bengal, India

Samanta, S.*, A. Choudhury and S.K. Chakraborty
Department of Zoology, Vidyasagar University, Midnapore 721 102, West Bengal, India.
Email: ss.lingula@gmail.com

Three different morphotypes of an intertidal macrobenthic brachiopod, *Lingula anatina* have been found to inhabit in three contrasting intertidal mudflats (based on different soil textures and vegetations) in an ecotone, the confluence of Subarnarekha estuary (21°35′48″ N and 87°27′17″E) within the Bay of Bengal, India. The species under study was very unique in respect of size, shape, texture and colour of shell and possesses longer lophophoral cavities, shorter ventral canals, long pedicle, well-developed posterior adductor muscles etc. showing phyllogenetic relationship with mesozoic lingulids. Gut content analysis and assessment of bioturbatory activities have established the roles of the studied species towards ecosystem functioning which also displayed distinct seasonal fluctuation of population density (0 No/m^2-2986±123.12 no/m^2), biomass (0 gm/m^2-1287.88±93.69 g/m^2) and size class (0-13.32 cm) in relation to the prime physico-chemical parameters such as salinity, pH, temperature, nutrients etc. of both soil and interstitial water during the period of July 2009 to June 2011. Different statistical analyses such as ANOVA, Duncan's Test, regression and correlation analyses have revealed the impact of tidal inundation and exposure along with other ecological variables in determining the occurrence, distribution and population fluctuation of this faunal component.

Revision of the fishes of the Genus *Bleekeria* (Perciformes, Ammodytidae)

Joshi, K. K.* and P. U. Zacharia
Central Marine Fisheries Research Institute, Kochi 682 018, Kerala, India. Email: joshyguru@gmail.com

Fishes of the family Ammodytidae popularly known as sand lances or sandeels, feed in aggregations on zooplankton over open sand bottom. They are very interesting group of small fishes adapted for zooplankton feeding such as protrusible premaxilla, short snout for binocular vision, reduced dentition and long gill rakers. The Ammodytidae consists of eight genera and two common genera are *Bleekeria* and *Ammodytes*. There are about eight species recorded in the genus *Bleekeria* of which only three are valid until recently. The valid ones are

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Bleekeria kallolepis Günther 1862, *B. mitsukurii* Jordan and Evermann 1902 and *B. viridianguilla* Fowler, 1931. During one of our fishery surveys, a few specimens of sand eels were collected from Tuticorin Fisheries Harbour on 8 June 2009 off the Gulf of Mannar, India and we described it as *Bleekeria murtii*. Recently, Randall and Ida (2014) described two new species ie *Bleekeria profunda* and *Bleekeria estuaria* from the southwest Indian Ocean and thus makes it a total of six species in this genus. We compared details of the types of the all six species of *Bleekeria* and reviewed the genus *Bleekeria*. The details of holotype *B. viridianguilla*, Fowler, 1931 (ANSP 53458) at Academy of Natural Sciences Philadelphia, USA, *Bleekeria kallolepis* Günter, 1862 (BMNH 1846.11.22) at Natural History Museum, London, *Bleekeria mitsukurii* Jordan and Evermann, 1902 (SU7133) at Californian Academy of Sciences, California, USA , *Bleekeria profunda* Randall and Ida, 2014 (SAIAB 84114) and *Bleekeria* estuaria Randall and Ida, 2014 (SAIAB 186240) are described.

Bleekeria viridianguilla Fowler, 1931: Dorsal rays 40-42, lateral line scales 108-111, eye diameter 4.7 % SL, back and upper body broccoli brown, sides and below pale vinaceous to whitish, no yellow bands, fins transparent without band.

Bleekeria kallolepis Günter, 1862: Dorsal rays 40-41, lateral line scales 100, eye diameter 4.3% SL, back and upper body bluish, with five yellowish horizontal bands. Dorsal fins with bluish base and yellow bands and anal with a bluish band.

Bleekeria mitsukurii Jordan and Evermann, 1902: Dorsal rays 42, lateral line scales 90-109, eye diameter 4.0 % SL, back and upper body greenish grey with yellow lines. Fins semitransparent.

Bleekeria murtii Joshi, Zacharia, Kanthan, 2012: Dorsal rays 35-49, lateral line scales 82-108, eye diameter 3.4 % SL, Grayish yellow on back shading to silvery white laterally and ventrally with yellow bands, dorsal fin transparent and the interspace of rays has yellow bands.

Bleekeria profunda Randall and Ida, 2014: Dorsal rays 49, pectoral-fin rays16, teeth present in the jaws, short pelvic fins (4.2 in HL), and 151 lateral-line scales.

Bleekeria estuaria Randall and Ida, 2014: Dorsal-fin rays 42, anal-fin rays 15, pectoral-fin rays 14, a short head, long pectoral fins, no pelvic fins, 99 lateral-line scales, a single scale dorsally on the preopercle, two scales dorsally on the opercle, and teeth present in the jaws.

The other genus in the family Ammodytidae i.e. the *Ammodytes* has five species and enjoys wide distribution and abundance (Belgium, Denmark, France, Germany, Ireland, Netherlands, Norway, Poland, Russia and U.K.). But this genus mainly occurs in the sub tropical and arctic seas. In the tropical seas *Ammodytes* is replaced by much smaller genera like *Bleekeria* and *Hyperoplus* which are characterized by smaller bodies and lesser number of vertebrae and presence of teeth. These tropical species must have been detached from the Ammodytidae to form distinct genus *Bleekeria*

A checklist of Acanthurids (Family Acanthuridae) from Indian waters

Rekha J. Nair*, S. Dinesh Kumar and Somy Kuriakose
Central Marine Fisheries Research Institute, Kochi 682 018, Kerala, India. Email: rekhacmfri@gmail.com

The Acanthuridae are the family of surgeonfishes, tangs, and unicornfishes which are reported to occur on coral reefs and rocky substrata, generally at depths less than 100 m from all tropical and subtropical seas. Some of these fishes are ornamental in nature and form part of the marine ornamental trade. A list of surgeon fishes in Indian waters is a prerequisite for correct biodiversity documentation. A survey of surgeon fishes along the coast of India, Lakshadweep and Andaman Islands was conducted during the period 2010-2013. Along with the list from published reports, a total of 40 species of surgeon fishes under 5 genera have been recorded from Indian waters, of which 3 species are new distributional records to the Indian waters. Collections were from Gulf of Mannar, Lakshadweep, Vishakapatnam and from Kochi.

Studies of seasonal variation in distribution pattern of brachyuran crab *Ocypode ceratophthalma* along the Saurashtra coast, Gujarat, India

Trivedi, J. N.* and K. D. Vachhrajani
Department of Zoology, M. S. University of Baroda, Vadodara 390 002, Gujarat, India.
Email: jntrivedi26@yahoo.co.in

Studies on the distribution and diversity of local fauna are of great importance because these studies lead to the best understanding of structure, function and problems of the local animal community. Organisms living in the intertidal area have to develop different kind of adaptations because they experience a wide range of physical stresses, including fluctuations in temperature, aerial exposure, salinity and hydrodynamic forces. Amongst all the species inhabiting intertidal zone, decapod crustaceans are one of the most diverse group of marine organisms. They dwell in variety of habitats and majority of the species occur in tropical and subtropical regions.

Gujarat has a longest coastline in the country which is of 1650 km and it is divided into three regions viz. Gulf of Kachchh, Saurashtra coast and Gulf of Khambhat. Saurashtra coast is very diverse in marine biota but the brachyuran crab fauna of the area is least studied or rather neglected; except the work of Chhapgar

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(1957), no literature is available on the status of brachyuran crabs. Out of all the brachyuran crab species reported from Saurashtra coast, *Ocypode ceratophthalma* is observed most abundant on the sandy shores. Though being most common species, the ecology of the species is not studied in detail. The present study deals with the seasonal variation in the distribution pattern of the *O. ceratophthalma*.

The study was conducted at four different sites located on the Saurashtra coast, viz. Veraval, Sutrapada, Dhamlej and Kodinar. The upper portion of intertidal area is made up of sandy shore. The width of the sandy shore varies at different sites with an average width of 20 meters. Quadrate sampling method was adopted for quantification of three different ecological attributes like density, abundance and frequency of occurrence. Total 50 quadrates ($1m^2$) were laid randomly every month at each site. All the burrows present in the quadrate were counted and burrow opening diameter of randomly selected burrows was measured. Monthly data was also collected for three different abiotic parameters of sediment viz. temperature, salinity and pH. The monthly data was compiled for different seasons like winter, summer and monsoon. The data was analyzed using different statistical method to obtain spatio-temporal variation in distribution pattern of the species.

The values of different abiotic parameters of sediment varied between different sites in different seasons. Strong correlation was recorded between burrow opening diameter and carapace length of the crab (Fig. 1). It was observed that larger burrows inhabited by adults of *O. ceratophthalma* were distributed on the upper part of sandy shore while smaller burrows inhabited by sub adults and juveniles were distributed near the water line. Number of burrows (Fig. 2) and spacing between burrows also varied from upper to lower part of the sandy shore. Significant seasonal variation was observed in the mean values of three different ecological attributes. The abundance of the species was recorded high as compared to density which implies that the species has patchy distribution in the study area. Maximum abundance of the species was recorded in pre monsoon season which is believed to be the peak breeding season of the species. The regression analysis showed strong correlation values for sediment pH followed by sediment temperature and sediment salinity with the abundance of the species. The correlation values also showed significant variation between different sites in different seasons. *Ocypode ceratophthalma* is one of the good indicator species of anthropogenic pressure on the sandy shores of the area. Information on the ecology and population structure of the species can be significant to lay the strong foundation for the formation of the better conservation policies.
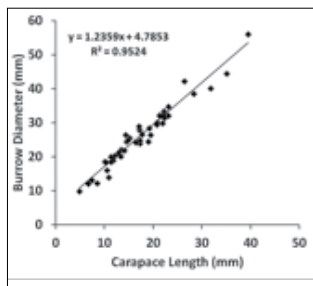
Fig. 1: Burrow diameter and crab carapace length relationship
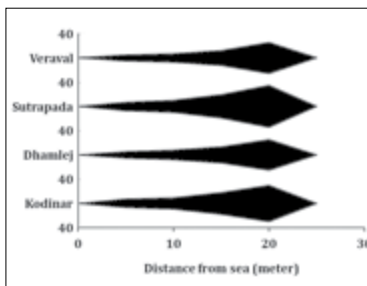
Fig. 2: Distribution of burrows of *O. ceratophthalma*

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Status of family Macrophthalmidae Dana, 1851 (Crustacea: Decapoda) from Gujarat state, India with new records of species

Soni Gunjan, M.*, N. Trivedi Jigneshkumar and K. D. Vachhrajani
Department of Zoology, M. S. University of Baroda, Vadodara 390 002, Gujarat, India.
Email: gunjansoni_247@yahoo.com

The intertidal zone is most productive and diverse ecosystem as compared to other ecosystems of marine environment. Amongst various fauna dwelling in the intertidal zone, brachyuran crabs are reported as most diverse and dynamic group. A total of 5000 species belonging to 45 families have been reported worldwide. Brachyuran crab species belonging to family Macrophthalmidae Dana, 1851 are majorly found in mangrove and mudflat habitats. Family Macrophthalmidae is distributed into three sub families viz. Macrophthalminae Dana, 1851, Ilyograpsinae Stevcic, 2005 and Tritodynamainae Stevcic, 2005. A total of 8 subgenera and 59 species have been reported so far under family Macrophthalmidae worldwide out of which 18 species have been reported from India.

Gujarat state has the longest coastline in the country which is 1650 km. The coastal areas of the state are majorly divided into three different regions viz. Gulf of Kachchh, Saurashtra coast and Gulf of Khambhat. The coastal areas of the state support various kinds of marine habitats but maximum coastal area is covered by mangroves and mudflats. Out of various fauna occurring on the coastal areas of the state, brachyuran crab fauna is least studied group. Chhapagar (1957) had carried out a study on brachyuran crab fauna of the state and reported 42 species which included 6 species belonging to family Macrophthalmidae. The present study was carried out to revise the status of family Macrophthalmidae in Gujarat state.

A total of 20 sites supporting mangroves and mudflat habitats along the Gujarat coast were surveyed for the collection of the crabs. Handpicking method was adapted for the collection of crabs. Sometime diluted formalin was also poured into the burrows to collect the crabs which one hiding inside the burrows. All the collected specimens were stored in ice box, brought to the lab and preserved in 10% formalin while some specimens were preserved in 70% alcohol for molecular studies. All the specimens were identified upto species level using various identification keys and deposited into Zoology Museum, Department of Zoology.The scientific names of the identified species were adopted from WoRMS website. Detailed morphometry of all the individuals belonging to different species was carried out. The specimens were photographed and color plates describing various morphological characters were prepared. The first left male gonopod was observed under microscope and sketched for all the species.

In present study, a total of 8 species belonging to the subfamily Macrophthalminae Dana, 1851 under genus *Macrophthalmus* Desmarest, 1823 were recorded which includes *Macrophthalmus dentipes* Lucas, 1836, *Macrophthalmus depressus* Rüppell,

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1830, *Macrophthalmus laevis* A.Milne-Edwards, 1867, *Macrophthalmus sulcatus* H. Milne-Edwards, 1852, *Macrophthalmus crinitus* Rathbun, 1913, *Macrophthalmus pacificus* Dana, 1851, *Macrophthalmus* (Mareotis) *japonicus* (De Haan,1835) and *Macrophthalmus brevis* (Herbst, 1804). *M. laevis* A. Milne-Edwards, 1867, has been reported to be commonly distributed in the coastal areas of Persian Gulf, Iran, Iraq and Pakistan but is reported for the first time from India during the present study (Fig. 1a), While *M. (M.) japonicus* (De Haan,1835) which has been previously reported from other coastal areas of the country was hereby reported for the first time from Gujarat state (Fig. 1b) in the shallow mudflats of Saurashtra coast.
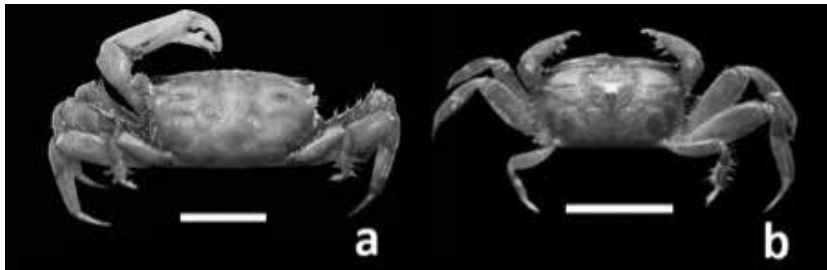
Fig. 1. (a) *Macrophthalmus laevis* A. Milne-Edwards, 1867 (b) *Macrophthalmus* (Mareotis) *japonicus* (De Haan, 1835). Scale bar in each case represents 1 cm.

In the present study, specific pattern is observed for the distribution of various species. *M. sulcatus* and *M. depressus* were distributed commonly in the study area while species like *M. laevis*, *M. crinitus* and *M. pacifics* were reported from single study site. The brachyuran crab species reported in the present study also showed specific kind of habitat preference in which species like *M. laevis* and *M. dentipes* were reported from mangrove habitat while rest of the species were reported from shallow mudflat habitat. Out of 8 species reported, maximum species diversity was reported from Gulf of Khambhat (5 species) followed by Gulf of Kachchh (3 species) and Saurashtra coast (1 species). The coastal areas of Gulf of Khmabhat support mudflat habitat which could be the possible reason behind the high species diversity because such kind of habitat is highly preferred by the brachyuran crab species belonging to family Macrophthlmidae.

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Diversity of coral reef associated fishes along Pondicherry, southeast coast of India

Jayaprabha, N.*, S. Purusothaman, K. Indira and M. Srinivasan
Centre of Advanced Study in Marine Biology, Annamalai University, Parangipettai 608 502, Tamil Nadu, India. Email: prabhamb12@gmail.com

The marine fishes reach their utmost diversity in the coral reef environment. Study on coral reef associated fishes along southeast coast of India is very scanty. Hence the present study has been focused on to assess the biodiversity of coral

reef associated fishes along Pondicherry, southeast coast of India. Based on the observation made for one year (January 2013- December 2013) totally 104 species of coral reef associated fishes belongs to 71 genera, 47 families and 16 orders were recorded. Among the 47 families Carangidae was dominated with 12 species followed by Serranidae (8 species), Lutjanidae (6 species) and Mullidae (5 species) and others with one to four species. Diversity data were analysed by using PRIMER (6.1). The maximum diversity, species richness were recorded during premonsoon and minimum were observed during summer. The Shannon diversity index ($\log^2$), Margalef richness, Simpson richness and Pielou's evenness were ranged from 4.4-4.7, 8.3-10.1, 0.922-0.939 and 0.73-0.76 respectively. Consequently, the present study revealed that Pondicherry is rich in reef associated fish diversity. Furthermore, the Cluster and MDS analysis exposed that there is a significant difference in the fish assemblages between the seasons.

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Migratory movement of *Lepidochelys olivacea* (Olive Ridley Turtle) along Tamil Nadu coast

Abhilash, K. S.*, R. Jeyabaskaran and V. Kripa
Central Marine Fisheries Research Institute, Kochi 682 018, Kerala, India. Email: abhilashks79@gmail.com

Lepidochelys olivacea (Olive ridley turtle) is most abundant marine turtle found along Indian coastline. It is the second smallest turtle after kemp's ridley turtle; these turtle weigh about 35-40 kg and reach 0.6m in length. Tamil and Andhra Pradesh are the coastal states which have shown presence of all five and four species of marine turtle respectively in their marine environment. Olive ridley turtle is found mostly in shallow coastal water on the eastern seaboard and found migrating to Orissa coast during from mid October to April/May. It is one among best suitable habitat for breeding and nesting in the world.

Cruise No. 290 of FORV *Sagar Sampada* which was exclusively designed to study benthic productivity and survey of gelatinous zooplankton along the South East Coast of India during October 2011. Visual survey based on the opportunistic sighting of marine mammal was also component of this scientific cruise. During the cruise a remarkable occurrence of turtles were seen along the Tamil Nadu coast. Approximately 300-400 turtles were sighted during the steaming of the vessel. The frequency of sighting was very while moving offshore. A brief reporting of the turtle sighting is described in this article. Area of sighting of the turtles started from off Karaikal (Lat 10°58.24 E: Long 80°015.8 N & Lat 10°589.9E: Long 80°421.3N) and extended to off Parangipettai (Lat 11°63.041E: Long 80°28.352 N & 11°634.2 E: Long 80°437.8N) at depth range from 200-1000m. Large number of olive ridley turtle were found as the cruise proceeded to offshore.

These turtles were floating and diving into the water and the number increased as the cruise progressed to eastward. The presence of these turtles during this time indicated the migration towards east to Orissa coast. This coast is known for

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synchronous mass nesting "arribada" exhibited by olive ridley turtles at Gahirmatha, Rushikulya and the Devi river mouth. Floating on the surface, diving deep for feeding and mating were observed and photographed during the sighting. Large patches of algal growth of red color were also seen attached on the shell of the turtle.

Another remarkable observation was marine litter impact on the habitat of the olive ridley turtles in these areas. Photographic evidence is presented in this article where two turtles are entangled by the plastic buoy and a plastic sack around its neck. These entangling around neck was not allowing the turtle to dive deep for feeding and hindered its movement. The ultimate fate of this turtle may be death due to starvation. They were exhibiting erratic movement with no proper swimming behavior like the other normal turtles. Also many fishing vessels were operating in these areas which may lead to accidental catch of the olive ridley turtles. An awareness campaign can be conducted among the fishermen operating these areas for conservation of turtles in these areas during migration to the breeding in this season. Since many reports suggest that these coastal water are migratory path for the olive ridley turtle to the "arribadas" in the Orissa coast.

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Rare sightings of masked booby (*Sula dactylatra*) off Karnataka and its possible relation with climate change

Lavanya, S.*, Bindu Sulochanan, G. D. Nataraja, Prathibha Rohit and V. Kripa
Central Marine Fisheries Research Institute, Mangalore Research Centre, Hoigebazar, Mangalore 575 001, Karnataka, India. Email: lavanyacmfri2010@gmail.com

Seabirds are an integral part of the marine ecosystem and play an important role in the nutrient and marine food web. Karnataka with a coastline of over 320 kilometers have numerous river mouths lagoons, bays, creeks, cliffs, sand dunes and beaches. The beaches and associated marine and estuarine habitats shelter many coastal birds. Migratory birds like terns and gulls are often sited along the coast. The Masked Booby (*Sula dactylatra*) not so frequently sighted bird was off the coast of Karnataka (N 13° 49′63″ and E 74°37′ 07″) in the Arabian Sea on 31.1.13. The booby was 72 cm long (from bill tip to tail end) with a wing span of 1.3 m and weighed 1.1kg. An earlier sighting of this bird was during June 2011 at Uppunda (N 13° 48′58.51″ and E 74°37′ 12.19″) with an injury on its wing during monsoon. The Masked Booby is a large seabird of the booby family Sulidae. The Masked Booby is widespread in tropical waters between 30°N and 30°S in the Pacific, Indian and Atlantic Oceans. This species breed on islands in tropical oceans, except in the eastern Atlantic. The largest Masked booby colony in the world with >100000 individuals is located in the eastern tropical Pacific on Clipperton Island. Masked Boobies are not migratory, however individuals may forage widely from their breeding islands in search of food. The foraging habitat is the open ocean, where prey is caught by deep-plunging. Masked boobies dive at an average depth of 2 m (maximum 12 m). The earlier sightings of Masked booby

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along the west coast of India is given in table 1. The maximum sightings were observed in the months of July and August.

Table 1 Previous records of sighting of Masked Booby (*Sula dactylatra*) along the West coast of India

Sl No.	Place of Occurrence	Period	ENSO index
1	Kadalundi, Malappuram , Kerala	July 1987	Warm
2	Chaliyam, Kozhikode, Kerala	August 1988	Cold
3	Uduppi, Karnataka	1988	Cold
4	Chavakkad beach, Thrissur, Kerala	July 1992	Warm
5	Udma, Kasaragod, Kerala	August 1994	Warm
6	Thaikadppuram, Kasaragod, Kerala	July 1998	Cold
7	Kadalundi, Malappuram, Kerala	Sept 2002	Warm
8	Mattul beach, Kannur, Kerala	July 2004	Warm
9	Karwar, Karnataka	August 2006	Warm
10	Thaikadappuram, Kannur, Kerala	August 2006	Warm
11	Pingleshwar coast, Kutch, Gujarat	13th July 2007	Cold
12	Chavakkad beach, Thrissur, Kerala	6th Feb 2008	Cold
13	Juhu beach, Mumbai, Maharashtra	20th June 2010	Cold
14	Asramam beach, Kollam ,Kerala	20th June 2010	Cold
15	Malvan , Sindhudurg, Maharashtra	4th July 2010	Cold
16	Marine Drive, Mumbai , Maharashtra	2nd August 2010	Cold
17	Off Kannur, Kerala	25th Sep 2010	Cold
18	12.31 km off Malpe Port , Karnataka	15th Oct 2011	Cold

Boobies are observed feeding exclusively in association with tuna and dolphins that drive fish to the surface. It feeds on shoaling fishes, especially flyingfish, but is known to feed on squids. Seabirds are specialized feeders and adaptation to new climates may be too slow and difficult. Hence there is a need for systematic studies to document seabird's diversity and breeding status. This paper also documents the coastal birds and seabirds off Karnataka. An attempt has also been made to study the relationship of ENSO with the sighting of rare birds.

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First record of two species of snapping shrimp of genus *Alpheus* from Gujarat

Purohit, B.*, D. Saini, G. M. Soni, J. N. Trivedi and K. D. Vachhrajani
Department of Zoology, M. S. University of Baroda, Vadodara 390 002, Gujarat, India.
Email: barkha1093@gmail.com

Crustaceans are widely distributed on the distinct microhabitats of inter tidal areas of Gujarat and thus are important macro-benthic fauna of the community. Among these, Prawns and shrimp is a large group of crustaceans since almost 2,500 species of prawn and shrimp belonging to 33 genera are reported the worldwide. In snapping (pistol) shrimp the Alpheus genus is the most abundant and diverse group. Most Alpheus species are free living in tropical worm water. They have symbiotic

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associations with coral, sea anemone, gobies and sponges. They are able to produce 118 dB sounds and this is the second loudest sound in the marine ecosystem. 250 species of Alpheus are described in the world where Indian contribution is of 11 species. In Gujarat, only *Alpheus digitalis* de Haan, 1844 is reported earlier. Primary surveys were carried out in the South Gujarat region between Kamboi (22° 12'N and 72° 37'E) and Umbergaon (20° 10'N and 72° 44'E) along the Gulf of Khambhat during April to June 2014. While exploring the nter tidal area at Umarsadi (20°31'N and 72°53'), district Valsad, Gujarat, the specimens of snapping shrimps were found. The Umarsadi coast has rocky shoreline overlaid by thin layer of mud. The specimens were collected during low tide time by hand picking method from the crevices and under surfaces of the rocks.

In the present study two species of genus Alpheus were found from the same habitat (Fig.1). They belong to Edwardsii group of Indo-West Pacific Snapping shrimp. The recorded genera are; *A. lobidens* De Haan, 1850 and *A. malabaricus* (Fabricius, 1775) belonging to genus *Alpheus* Fabricius, 1798, family Alpheidae Rafinesque, 1815 and infraorder Caridea Dana, 1852. Many Alpheus shrimp species are closely similar. *A. lobidens* is widely distributed in entire Indo-West Pacific, Japan, Mediterranean Sea, Red Sea and South Africa while, *A. malabaricus* is distributed along the Mediterranean Sea and Red Sea. In India, these species are reported earlier from south east coast and Kerala and are reported for the first time from Gujarat. The specimens of each species were preserved separately in 10% formalin and absolute alcohol for taxonomic identification. The specimens were photographed when fresh and sketches of characteristic features were drawn for further identification purpose. The identification up to species level was confirmed using various illustrative and descriptive keys. The specimens were deposited in the museum of Department of Zoology, The Maharaja Sayajirao University of Baroda, Vadodara.
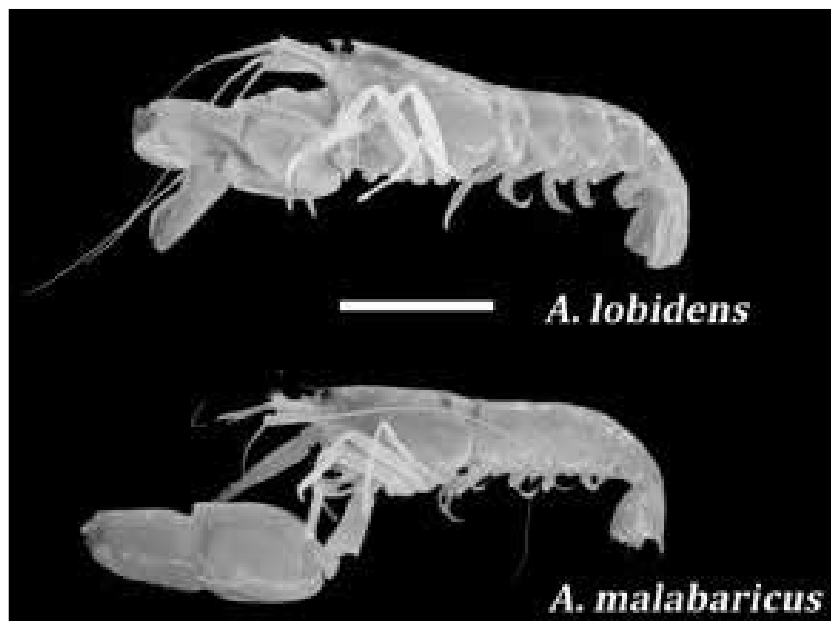
Fig.1. Two species of *Alpheus* (scale bar represents 1cm)

One specimen of *A. lobidens* and six specimens of *A. malabaricus* were examined. These are complex species and are similar to *Alpheus pacificus* Dana, 1852. In *A. malabaricus*, two spines are present on merus of major chela, size of propodus and dactylus of minor chela is almost equal; dactylus is 3.0 times as long as palm but in A. lobidens, the spine is absent on merus of major chela, dactylus width is 3 times more than propodus of minor chela, dactylus is almost sub-equal to palm. Penultimate article tip of 3rd maxilliped is curved in *A. malabaricus* and reaching up to the middle of merus. But in *A. lobidens* the penultimate article is straight and reaching up to the end of ischium. These are the most significant difference between these two species.

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Indo-Pacific finless porpoise *Neophocaena phocaenoides* incidentally caught off Uppunda, Karnataka

Bindu Sulochanan*, S. Lavanya, A. P. Dineshbabu and V. Kripa
Central Marine Fisheries Research Institute, Mangalore Research Centre, Hoigebazar, Mangalore 575 001 Karnataka, India. Email: binduchaithanya@yahoo.co.in

Indo-Pacific finless porpoise, *Neophocaena phocaenoides*, is a cetacean inhabiting the coastal and marine waters of Karnataka as well as the west and east coastal waters of India. It has been described as facultative river cetaceans. These inhabit fresh water as well as coastal and marine waters. They are also found in warm, shallow coastal waters of the Western Pacific oceans. It is endemic to southern and eastern Asia. This marine mammal is the only porpoise that lacks a dorsal fin and instead has a ridge along the middle of its back. Historically, the genus *Neophocaena* contained only one recognised species, the finless porpoise *N. phocaenoides*. It has very recently been split into two species: the Indo-Pacific finless porpoise *N. phocaenoides* and the narrow-ridged finless porpoise *N. asiaeorientalis*, formerly recognized as the subspecies *N. phocaenoides asiaeorientalis*.

A pod of seven porpoises were incidentally caught in purse seine, 1.5 km off Uppunda, Karnataka, southwest coast of India. These had wide area of tubercles which is the one inhabiting Indian waters. The tubercle widens near the end point of joining of flipper on dorsal side and extends to the tail flukes. The function of these tubercles is unknown, but they possess an abundance of nerve endings, suggesting that they serve some sensory function. The tubercles are believed to act as anti-slip surface when female carries its calf on its back. The flippers are long, with blunt tips. The young calves are said to travel clinging to their mother's backs. The mammal has slender body which is dark to pale grey on the upper side and lighter on the underside. Colouration is paler on the juveniles with light pink colour on the underside with eyes pink. The data on abundance, reproduction, feeding habit and the habitat preference of these are lacking. Finless porpoises are generally found as singles, pairs or in groups up to 20-50. They are fast and agile swimmers. They do not ride the bow waves of

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boats like dolphins, but do get caught in purse seines when pursuing feed. They are susceptible to bycatch in fishing gear. Uppunda has a rocky coastal belt and the adjacent estuary is rich in mangroves. This is the breeding ground for most of the prey items found in the study. The porpoise off Uppunda was analysed to understand the dominant prey items. The dominant prey items were white sardine *Escualosa thoracata* followed by shrimp like *Metapenaeus dobsoni* and *Parapenaeopsis stylifera*.

In Japanese and Chinese waters reproduction of *N. phocaenoides* studies show that the maturity of both sexes occurs at 3-6 years of age with a length of 132-150cm. Calving is observed to occur at different times of the year, with peak calving season varying with location. The morphometric measurements were taken of a female mammal carrying an unborn calf. The mother *N. phocaenoides* measured 135 cm, while the unborn calf was 46.5 cm. Calving could have occurred during April/May. It is estimated that the gestation period of this species is around 11 months and that the mother feeds her calf for approximately seven months.

Habitat degradation and human interference is cited as reasons for vulnerability of these mammals. With some of the largest concentrations of humans in the world living along the shores and harvesting the resources from the warm coastal waters inhabited by Indo-Pacific finless porpoises, the impacts of human activities on this species especially due to destruction of mangrove habitat must be considerable. Considerable numbers of finless porpoises have been killed by bottom set longlines and encircling gillnets. Regional declines of *N. phocaenoides* have been reported, presumably due to fishing pressure, coastal development and industrialization, pollution and heavy vessel traffic. Awareness of the mammals breeding and feeding ground can help in its conservation.

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Applications of remote sensing on biodiversity conservation and management in coastal marine ecosystems

Nammalwar, P. *, V. S. Gowri and R. Ramesh
Institute for Ocean Management, Anna University, Chennai 600 025, Tamil Nadu, India.
Email: drnrajan@gmail.com

India has made tremendous progress and significant achievements in space technology especially in the field of remote sensing applications over the past three decades. Conventional and timely availability of adequate data on a variety of parameters on a routine basis are essential for conservation and management of ocean and coastal resources. The unique capabilities of satellite based sensors in providing a repetitive and synoptic coverage of inaccessible/ larger areas at frequent intervals has made the remote sensing technology an effective tool in the sustainable development and management of environment and resources. The coastal marine ecosystems play a

vital role in India's economy by virtue of their natural resources, potential habitats and wide biodiversity. India has a long coastline of 8129 km with Exclusive Economic Zone (EEZ) of 2.5 million km² which is an important area both for exploration and exploitation of natural resources. Marine biodiversity affords enormous economical, environmental and aesthetic value to mankind. Marine organisms also rely upon the great biodiversity of habitats and resources for food, breeding and larval dispersal in the environment. The valuable marine aquatic resources are now becoming increasingly susceptible to both natural and manmade environmental changes.

The spatial and thematic aspects of remote sensing technology enable users to overlay various data to delineate and predict the future of our natural resources. The applications of remote sensing methods are gaining momentum in various field of marine sciences such as coastal wetland assessment, coastal vegetation, mangroves, coral reefs, sea grasses, seaweeds, marine biodiversity, fish shoals/fishery potentials, ocean color, plankton biomass, lagoon ecosystems, coastal aquaculture, oil and mineral explorations, weather predictions, forecast of natural hazards and vulnerability assessment. The huge amount of databases, generated into an information system form a scientific tool for the environmental managers, scientists, planners, government agencies to device suitable strategies for management of coastal and marine resources.

Ecological systems are dynamic and components and conditions change with time. Remote sensing and environmental modeling provides new capabilities for analyzing the space/time distribution of ecological phenomena. These predictive capacities are needed to supplement traditional descriptive inventory of biodiversity. The present paper analyses the various applications of remote sensing on biodiversity those are necessary to maintain and support the availability of natural resources in the coastal marine ecosystems.

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Study of stress parameters in the hepetopancreas of brachyuran crab *Scylla serrata*

Pareek, R.*, S. Arya , J. N. Trivedi and K. D. Vachhrajani
Department of Zoology, M. S. University of Baroda, Vadodara, Gujarat, India.
Email: pareekricha333@gmail.com

Animals residing in different marine habitats require specific conditions for their survival. A change in such conditions, beyond their adaptive potential, can cause adverse effect on the growth and survival of the animal. However, some animals can resist to such deleterious conditions and, therefore, can be used to predict the condition of an ecosystem. The crustaceans have been recently studied extensively as pollution indicator species. Brachyuran crabs play important role in the maintenance of the coastal ecosystem. Therefore, they are considered significant indicator of pollution. The Gujarat state has a longest coastline in the country (1,650 km) which has played a key role in the industrial development of

the state. Due to the industrial development, the coastal areas of the state are facing high amount of chemical pollution. In the present study brachyuran crab *Scylla serrata* was used as an animal model to check the effect of coastal pollution as it is commonly distributed along the coastal Gujarat and is a commercially important species.

The specimens of *Scylla serrata* were collected from two different sites viz Alang and Nada located in Gulf of Khambhat. Alang, was selected as high pollution site because the coastal areas of the site receives chemical pollutants due to the ship breaking industry. Nada was selected as control (less polluted) site which is located beyond the industrial zone of South Gujarat. Biomarkers provide the most accurate indication for the pollution status of an ecosystem. Total 18 live specimens, 9 males and 9 females, of *Scylla serrata* were collected from local fish markets of each study site. It was confirmed that the specimens were freshly collected from local coast. The specimen were stored in ice box and brought to the laboratory. Carapace length and weight of all the specimens were recorded and the specimens were segregated into various size classes and weight classes. All the specimens were dissected and hepatopancreas was removed from the specimens. The tissue samples were marked with specimen number and stored at -20˚C. The tissues were analyzed for various biomarkers like lipid peroxidation (LPO), glutathione peroxidase (GPX), reduced glutathione (GSH) and catalase (CAT) using standard methods. Total protein content was also determined.

The results showed variations between the two sites. The values of LPO and GPX showed high variation between Alang and Nada. Animals of both the sexes showed significantly high values for LPO and GPX activity at Alang as compared to Nada. The values of GPX showed significant variations but values of LPO did not show significant variations for females (Fig. 1a and 1c). The males from Alang showed high but non-significant values of catalase as compared to that at Nada. In case of females, little variation was observed for catalase values between both the sites. The GSH values were recorded slightly higher at Nada as compared to Alang for both males and females but the variation in GSH values between different sizes was not significant (Fig. 1b and 1d). Specific pattern was observed for the values of stress parameters between different size classes of males and females in which the values of stress parameter increase with body size of the animal. In the case of
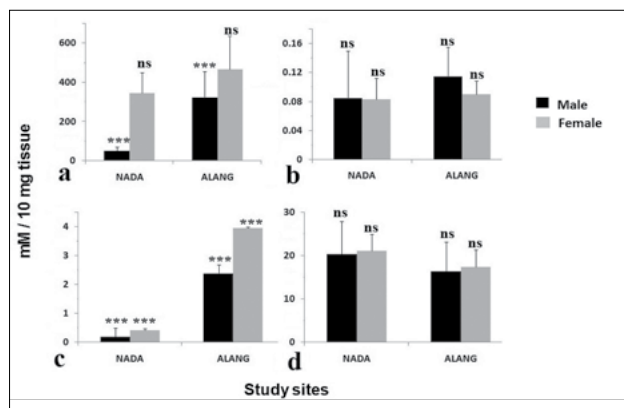
Fig. 1. Values of different stress parameters in hepatopancreas of *Scylla serrata*.
a. LPO; b.CAT; c. GPX; d. GSH; *** (P<0.001), ns- Not significant.

weight classes of the crabs, high stress parameter values were observed for lighter and younger animals.

The results showed that the population of brachyuran crabs *Scylla serrata* inhabiting the coastal areas of Alang are under stressful conditions created by the chemical pollution. Due to the specific sea water flow pattern in Gulf of Khambhat the chemical pollution occurring in Alang is spreading in other areas of Gulf. To check the effect and spread of chemical pollution in Gulf of Khambhat, stress parameters studies on various benthic fauna is very much needed.

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Marine litter constituents on selected beaches in Tuticorin, Gulf of Mannar

Asha, P. S.*, K. Diwakar, G. Santhanavalli and P. Kaladharan
Central Marine Fisheries Research Institute, Tuticorin Research Centre, South Beach Road, Tuticorin 628 001, Tamil Nadu, India. Email: ashasanil@gmail.com

Marine litter accumulated along beaches has been recognized as an indicator of pollution that affects the aesthetic appeal of beaches and causes risks to marine organisms. The marine litter constituents on four beaches of Tuticorin were quantified during the period 2009 - 2011. The Threspuram beach (St.1) nearer to the fish landing centre is highly polluted due to the waste accumulated from the discharge of untreated sewage and garbage. Tharuvaikulam beach (St.4) and Mottaigopuram beaches (St.2) are disturbed due to the interference from fishing activities. Tuticorin harbour beach (St.3) though a recreational beach, is also under the threat of fishing activities. Litter were collected on a monthly basis using a rope quadrate of 10 x 10 m size and graded into five major groups.

Among the litter constituents, plastic (group-B) contributed the major share and constituted 14 to 100% of the total constituents. The share of plastic was comparatively higher during 2009 and lower during 2011 and the biomass ranged between a minimum of 16.04 $g.m^{-2}$ at St.2 (Mottaigopuram beaches) to the maximum of 405 $g.m^{-2}$ at (St.1) Threspuram beach during 2009, 6.85 $g.m^{-2}$ at St.2 to 365 $g.m^{-2}$ at St.1 during 2010, 0 at St.4 in 2011 to 278 $g.m^{-2}$ at St.1 during 2011 respectively. Highly significant difference was noticed in the annual variation of plastics among beaches ($p<0.001$). Plastics were comparatively higher during north east monsoon season and November month registered the highest, indicating rainfall and associated land runoff are the major source of plastic pollution. Highly positive correlation was also noticed between plastics and rainfall ($p<0.01$) and a negative correlation was noticed between plastic and wind speed ($p<0.01$). The mean value was minimum of 71.2 ± 22.8 $g.m^{-2}$; 32.7 ± 22.8 $g.m^{-2}$ at St.2 during 2009 and 2010 and 37 ± 11.8 $g.m^{-2}$ at St.4 during 2011 and the maximum of 218.5 ± 56.3 $g.m^{-2}$ in 2009, 195.7 ± 24.9 $g.m^{-2}$ in 2010 and 150.2 ± 22.8 $g.m^{-2}$ in 2011 at St.1. Highly significant difference was noticed in the variation of plastics between stations ($p<0.001$).

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Sacs (group-B) comprised the second major component and contributed up to 82% of the total constituents. The biomass ranged from 0-720 $g.m^{-2}$ at St.1 during 2009., 0 to 80 $g.m^{-2}$ at St.3 during 2010, 0 to 150 $g.m^{-2}$ at St.3 during 2011. They were absent at St.2 and 4 during 2010 and at St.1, 2 and 4 during 2011. The annual variation was significant among stations ($p<0.01$). The biomass was maximum during the high speed wind season especially during June-July period. The mean value was highest of 157 ± 140.7 $g.m^{-2}$ at St.1 followed by 143.04 ± 115.5 $g.m^{-2}$ at St.4 during 2009. Fibers (group-C) constituted the third important component and was present throughout at St.1 and 3; at St.2 and 4 during 2010. The biomass ranged from 0 to 550 $g.m^{-2}$ at St.1, 0 to 2.9 $g.m^{-2}$ at St.2, 0 to 500 $g.m^{-2}$ at St.3 and 0 to 171 $g.m^{-2}$ at St.4. The mean value was maximum of 174.4 ± 86.7 $g.m^{-2}$ at St. 3 during 2009, 36.7 ± 16.7 $g.m^{-2}$ during 2010 and 131 ± 92.2 $g.m^{-2}$ at St.1 during 2011. Significant difference was noticed in the variation of fibers between stations ($p<0.001$).

Thermocol (group-F) the fourth major component, comprised 0 to 35.9 $g.m^{-2}$ at St.1 during 2009, 0 to 70 $g.m^{-2}$ at St.1 during 2010 0 to 90 $g.m^{-2}$ at St.3 during 2011 respectively. The mean value was maximum of 8.18 ± 6.9 $g.m^{-2}$ at St.1 during 2009, 13.8 ± 6 $g.m^{-2}$ at St.2 during 2010, 35.8 ± 11.8 $g.m^{-2}$ at St.3 during 2011. The seasonal as well as annual variations were statistically significant among the beaches (p <0.05). Metals (group-E) was the least represented item among the constituent, it was reported only from St.1 during the period 2009 and 2010. The mean biomass was maximum of 28.04 ± 17.2 $g.m^{-2}$ at St.1 during 2009. The studies indicated that the poor management of domestic waste is the major source of litter accumulation in beaches of Tuticorin rather than the recreational and fishing activities.

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Mussel watch: Metal contamination assessment in Vembanad Lake

Prema, D.*, V. Kripa, Jenny Sharma, G. Shylaja, Preetha G. Nair, K. S. Aswathi , K. S. Abhilash, Rakesh Sharma, R. Jeyabaskaran and P. Kaladharan
Central Marine Fisheries Research Institute, Kochi 682 018, Kerala, India. Email: premadicar@gmail.com

Bivalves are filter feeders and are known as bio-indicators of the environment in which they live. Mussels are widely used for assessing the status of coastal environmental health, especially to monitor trace metal accumulation in the ecosystem. Trace metals in the ecosystem can exceed the permissible level by way of increased industrial pressure and other anthropogenic activities; particularly in the coastal areas.The present study was initiated in order to evaluate the trace metal accumulation in Vembanad Lake (VL), opening to the Arabian Sea.

Seeds of green mussel (*Perna viridis*) of weight ranging from 2.66 to 8.34 g collected from Neendakara Bay of Ashtamudi Lake in December 2012, were stocked at Moothakunnam, Munambam, Cherai and Njarakkal of VL system.

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The content of Pb, Cd, Cu and Zn in water collected from these locations were analysed during March to June 2013, using Voltammetry. Tissue samples of mussel were subjected to microwave digestion and assessed for initial and final content of metals viz. Cu,Pb,Cd and Zn using Atomic absorption Spectrophotometer.

The Cu content in water was below permissible level of 1000 ppb as per the stipulated limit of USEPA (1986) in the VL study to locations. The Zn content in water in all these stations system. Was also below permissible level of 1000 ppb as per the stipulated limit of USEPA (1986). The Pb and Cd in water were found NOT DETECTED during March - May but detected in June.The values were below permissible level of 50 ppb and 10 ppb respectively as per the stipulated limit of USEPA, 1986.

The Cu content in tissue was not detected in the initial meat sample from Neendakara Bay, as well as in the final samples from the stations viz. Moothakunnam, Munambam, Cherai and Njarakkal at VL. In Neendakara Bay (3.33 ppm) and in VL, in the stations viz. Moothakunnam, Munambam, Cherai and Njarakkal, the meat samples contained Pb (4 to 7 ppm), below the permissible level (9 ppm) as stipulated by WHO (1987), on dry weight basis. The Cd content in meat sample at Neendakara Bay (0.44 ppm) and in the above mentioned VL stations (0.37 to 1.57 ppm) were below the permissible level for Cd (9 ppm) as stipulated by WHO (1987), on dry weight basis. The content of Zn in meat sample from Needakara Bay (64.19 ppm) and in the final samples from the same stations at VL (59.79 to 78.52 ppm) also were much below the permissible level (217 ppm) as stipulated by WHO (1987), on dry weight basis.

The above results indicate the suitability of the selected sites, viz. Moothakunnam, Munambam, Cherai and Njarakkal at VL for clean mussel/bivalve farming. No threats of the selected metal contamination or bioaccumulation above the permissible level in water or meat were observed during the grow-out period of six months. The meat was found to be safe for consumption withregard to the selected metal accumulation in the site.

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Processes responsible for spatial variations in macrobenthic infaunal community in a tropical monsoonal estuary (Godavari, India)

Naidu, S. A.* and V. V. S. S. Sarma
National Institute of Oceanography, Regional Centre, Visakhapatnam, Andhra Pradesh, India
Email: naidu.sura@gmail.com

Estuarine environments serve as an important nursery to host pisces, which feed on benthic macrofauna. Benthos play a significant role in ecosystem processes such as recycling of organic carbon in the sediment and act as a source of nutrients to the water column. Abundance, distribution and diversity of macrofauna were examined in a tropical monsoonal estuary, Godavari, during no-discharge

period. Total of 37 macrobenthic species were identified during this study, in which polychaeta (82%) was the dominant group followed by crustacea (14%), bivalvia and others (4%). Among the polychaetes, Prionospio cirrefera (39%) contributed significantly higher, followed by Polydora sp. (23%), Nephtys sp. (5%) and Magelona cincta (3%), while in crustacean, Amphipods (13%) was the most abundant. Based on trophic guilds, macrofaunal communities were numerically dominated by deposit feeders (90%) followed by carnivores (7%), omnivore and filter feeders (3%). The deposit feeders showed significant spatial variability with an increasing trend from upper to lower estuary. Despite high particulate organic matter (POM), phytoplankton biomass and lower grazing pressure at upper estuary, the accumulation of organic matter into the sediment is low due to high residence time of water and decomposition within the water column itself. This was further confirmed by high partial pressure of CO_2 in the upper estuary by 3 to 4 times compared to that of lower estuary. In addition to this, sand contributed significantly (78%) to the sediment in the upper than lower estuary that further aided to decompose organic matter in the sediment. As a result low abundance of macrofaunal communities was observed in the upper compared to lower estuary where contrasting conditions were found. This study reveals that characteristics of both water column and sediment are responsible for spatial variation in the macrobenthic community structure in the tropical Godavari estuary.

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Distribution pattern of different zooplankters along the Chennai coast in relation to environmental parameters

Hemasankari, P.*, A. Ahamed Kamal Basha, P. Kaladharan and V. Kripa
Central Marine Fisheries Research Institute, Madras Research Centre, 75, Santhome High Road, Chennai, Tamil Nadu, India. Email: sankarihema@yahoo.com

Zooplankton plays a key role in the marine food web by transferring the organic energy produced by the unicellular algae through photosynthesis to higher trophic levels such as pelagic stocks. Zooplankton recorded in the present study includes, Hydrozoa, Siphonophora, Polychaete, Pteropods, Copepoda, Decapoda, *Lucifer* sp., Mysid, Chaetognaths, Copelata, and Fish Eggs. The occurrence of zooplankton and the indices of Shannon's Index, Species richness, Evenness Index, Simpson's Diversity index and dominance index were correlated with environmental parameters, temperature, salinity, p^H, dissolved oxygen, total soluble solids, chlorophyll a, b & c, gross and net primary productivity, nutrients, phosphate, nitrate and ammonia. In Chennai fisheries harbor region, temperature is most positively related to the abundance of fish eggs (r=0.199), Copepoda (r=0.129), Siphonophora (r=0.038). Salinity is most related to the occurence of the fish eggs (r=0.426) and Siphonophora (r=0.106). P^H is related to the occurrence of, *Hydrozo* (r=0.200), *Siphonophora* (r=0.199), *Polychaete* (r=0.013), *Pteropods*, (r=0.118), *Copepod* (r=0.373)*, Decapoda* (r=0.233), *Mysid* (r=0.158), *Chaetognaths* (r=0.050). Fish eggs, (r=0.496) is most related to the p^H and is least

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related to the Copelata (r=0.010). Increased dissolved oxygen is the indication of the occurrence of *Copepoda* (r=0.660) and least related to the *Polychaete*, (r=0.087). Chlorophyll a is related to the occurrence of *Copepoda* (r=0.526) and least related to the *Polychaete* (r=0.100). Chlorophyll b is related to *Polycheate* (r=0.295) and least related to *Pteropods* (r=0.073). Chlorophyll c is most related to *Decapoda* (r=0.329) and least related to the *Polychaete* (r=0.009). Primary productivity, gross is most related to the occurrence of *Polycheate* (r=0.680) and least related to the occurrence of *Mysid* (r=0.433). Primary productivity, net is related to the *Mysid*, r=0.403 and least related to the *Copepoda*,r=0.144. The nutrient Phosphate is related to the occurrence of fish eggs, r=0.379 and least related to the occurrence of the *Polychaete*, r=0.049. The nutrient ammonia is related to the occurrence of the *Decapoda*, r=0.400 and least related to the *Lucifer*, r=0.056.

Dominance Index is more in *Decapoda* followed by Mysid, Pteropods, Chetognaths, Hydrozoa, Copepoda, Polychaete, *Lucifer* sp., Copelata and fish eggs. Simpson's diversity index is more in fish eggs followed by Copepod, Decapoda, Mysid, Chaetognaths, Pteropods, Hydrozoa, Polycheate, Copelata and *Lucifer* sp. and least in Siphonophora. Shannon's Index is directly related to evenness index and species richness. Dominance index is directly related to Simpson's diversity index. Species richness is directly related to evenness index. Simpson's diversity index is related to nutrient ammonia, chlorophyll b, dissolved oxygen, primary productivity, gross and net. Dominance index is related to nutrient, chlorophyll c, gross, primary productivity, chlorophyll a, dissolved oxygen, salinity, chlorophyll b and pH. Evenness index is related to the phosphate, temperature, nitrate and net primary productivity. Species Richness is related to the nitrate (r=0.989), phosphate (r=0.521), chlorophyll c (r=0.325), chlorophyll a (r=0.247), pH (r=0.072), salinity (r=0.069) and temperature (r=0.049). Shannon's index is related to nitrate (r=0.580), phosphate (r=0.414), temperature (r=0.246), net primary productivity (r=0.178) and P^H (r=0.042). Temperature is most related to evenness index (r=0.272) and least related to the species richness (r=0.049). Salinity is most related to dominance index (r=0.188) and least related to the species richness (r=0.069). P^H is most related to the species richness (r=0.082) and least related to the dominance index (r=0.014). Dissolved oxygen is most related to Simpson's diversity index, and least related to the dominance index. Chlorophyll a is most related to the dominance index, and least related to the species richness. Chlorophyll b is most related to the Simpson's diversity index (r=0.325) and least related to the dominance index (r=0.151). Chlorophyll c is most related to the dominance index (r=0.388) and least related to the species richness (r=0.325). Gross Primary productivity, is most related to the dominance index (r=0.340) and Simpson's diversity index (r=0.234). Net primary productivity is most related to the Shannon's index) and least related to the Simpson's diversity index. Phosphate is most related to the species richness (r=0.521) and least related to the evenness index (r=0.279). Nitrate is most related to species richness (r=0.989) and least related to evenness index (r=0.251) and the ammonia is most related to dominance index (r=0.571) and least related to Simpson's diversity index (r=0.341).The study is significant at 5% (p≤0.05) level of significance.

Diversity of macrobenthos and its relation to environmental parameters in the estuaries of west coast, Tamil Nadu, India

Purusothaman, S.*, K. Sakthivel and K. Kathiresan
Centre of Advanced Study in Marine Biology, Annamalai University, Parangipettai 608 502, Tamil Nadu, India. Email: purusothaman30@gmail.com

Macrobenthos is an important component of estuarine ecosystems and plays an important role in the system dynamics. In the present study the diversity of macrobenthos and their relationships between physico-chemical parameters of the water in different estuarine habitats in west coast of Tamil Nadu during different seasons (2012 and 2013). During summer season, as many as 20 species of macrobenthos were recorded. Of these, polychaetes were found to be the dominant group with 16 (80%) species followed by bivalves (3 species) and gastropod one species. During monsoon season, a total of 13 species of macrobenthos consist of polychaetes 10 species, bivalves two species and gastropod one species. In pre-monsoon season, 16 species of macrobenthos such as polychaetes (10 species), bivalves and gastropods three species each were recorded. Among the different estuarine ecosystems, benthic faunal assemblages, macrofauna species number, density, richness, and Shannon-Wiener index and Pielou Evenness index, taxonomic diversity and phylogenetic diversity were the highest at riverine estuarine community. The similarities among the macrobenthic communities at different sampling sites were determined using Bray-Curtis similarity coefficient and ordinations of non-metric multidimensional scaling (MDS). Water temperature was found to vary from 24.0 to 29.5°C, salinity varied between 18 and 2.5 ‰, dissolved oxygen content varied from 1.01 to 5.24 ml.l^{-1}, pH varied between 7.3 and 8.3. The maximum water temperature and dissolved oxygen was recorded during summer and minimum was during monsoon. The maximum salinity and pH values were observed during pre-monsoon.

Spatial variation of zooplankton along south west coast of Kerala

Ajith Joseph, C.*, Soumya Krishnankutty, P. D Vincent, M. Nashad, P. M. Greeshma, Jemi Job, P. S. Vishnu, A. V. Saramma, and A. A. Mohamed Hatha
Department of Marine Biology, Microbiology and Biochemistry, School of Marine Sciences, Cochin University of Science and Technology, Lakeside Campus, Kochi 682 016, Kerala, India. Email: jcajith@gmail.com

Zooplankton species distribution shows wide spatial variations due to the different hydrographical factors on individual species. This diversity and abundance of

the community structure of the zooplankton is necessary to assess the potential fishery resource of a place. The study addresses the coupled spatial scales in the physico-chemical variables and zooplankton with respect to diversity, density and abundance in the west coast of Kerala during the 2013-14 post monsoon (Oct-Jan) period. Zooplankton samples were collected from the surface waters along each station by horizontal surface towing of plankton net (mouth area 0.25m^2, mesh size 200μm) for 10 min which was employed in 10m and 30m depths of three stations namely Valiyathura (Trivandrum), Neendakara (Kollam) and Vypin (Ernakulam). The relationship between the physico-chemical parameters such as temperature, dissolved oxygen (DO), pH, salinity, nitrite, nitrate, phosphate and silicate with that of zooplankton biomass and composition were studied. Community analysis showed Valiyathura having low diversity high biomass community while Neendakara and Vypin showed high diversity low biomass community. All the stations were dominated by copepods which constituted nearly 50% of the samples. Of the physico chemical parameters salinity showed significant positive correlation with zooplankton biomass.

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Depth-wise variation of zooplankton diversity and composition in the inshore waters off Tuticorin, Gulf of Mannar

Asha, P.S.*, N. Selvaranjitham, K. Diwakar, H. Sivanesh and E. Vivekanandan
Central Marine Fisheries Research Institute, Tuticorin Research Centre, South Beach Road, Tuticorin 628 001,Tamil Nadu, India. Email: ashasanil@gmail.com

Zooplankton plays a major role in the functioning of aquatic systems and their species composition and densities are important in determining the trophic level. The present study was conducted to assess the depth-wise variation in the zooplankton composition and diversity off Tuticorin during the period April 2011 to March 2012. Fortnightly sampling of zooplankton were carried out while observing hydrographical parameters during the full moon and new moon days to analyse the impact of lunar cycle and the relationship with hydrological parameters.

The settlement volume of zooplankton varied between 1- 49.2 ml. Comparatively, a higher settlement volume was observed at 15 m depth and lower at 5 m depth. The settlement volume increased with increasing numbers of zooplankton constituents. The biomass of zooplankton was higher towards the new moon period especially in the shallowest 5 m depth and varied between the lowest of 0.07 ml.m^{-3} in the full moon samples at 15 m depth to the highest of 38.5 ml.m^{-3} in the new moon samples at 5 m depth.

Copepod constituted the most dominant group and comprised 12.2 to 88.8 % of the total population and the density varied between a minimum of 6500 nos.l^{-1} at 5 m depth to the maximum of 609000 nos.l^{-1} at 15 meter depth. Decapod was the

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second dominant group and constituted 1.32 to 53.8 % of the total population. The density varied between 4000 to 238500 nos.l^{-1}. *Lucifer* constituted the third dominant group and comprised a maximum of 58 % of the total population during new moon period and the density ranged between 0 to 1,08,000 nos.l^{-1}. Fish eggs, the fourth dominant group constituted a maximum of 44.92% of the total population and the density varied between 0 to 109330 nos.l^{-1}. Cladocerans, the fifth dominant group comprised a maximum of 56.02% of the total population and the density varied between 0 to 9,00,500 nos.l^{-1}. *Alima* larva and chaetognath represented the sixth and seventh major groups respectively.

At 5, 10 and 15 meter depths, the species richness index "D" was comparatively higher during the new moon period and varied between the lowest of 0.56 during Apr'12 at 5 meter depth to the highest of 1.47 during Sept'11 at 20 meter depth. The diversity index "H" varied between a minimum of 0.60 bits. Individual during Dec'11'at 15 m depth to a maximum of 2.04 bits.

The studies indicated the congregation of *Lucifer* and cladocerans towards 10 m depth and copepod, decapods and fish eggs towards 15 m depth, but the depth wise variation was significant only for decapods ($p < 0.05$). Swarming of constituents like decapods, *Lucifer*, fish eggs, alima and bivalve larvae were more towards the full moon period and groups like copepod, cladocerans and chaetognath were more towards the new moon period, but the full moon and new moon variation was statistically significant only for bivalve larvae ($p < 0.05$). Copepod showed negative correlation with SST ($p < 0.05$) and a positive correlation with fish eggs, decapods, chaetognath, cladocerans and *Alima* larvae ($p < 0.01$). Decapod showed positive correlation with mysis, bivalve larvae and *Alima* larvae ($p < 0.05$). Fish eggs showed positive correlation with decapods larvae, mysis, bivalve, *Alima* larvae, salinity, silicate and transparency ($p < 0.01$). Cladocerans showed positive correlation with *Alima* larvae, NO_2 and PO_4 and negative correlation with SST ($p < 0.05$).

Not much variation could be observed in the SST, salinity and pH between stations. The SST ranged between 25 to 32.2°C with the highest mean value of 29.5±0.5°C in the shallowest 5 meter depth. The salinity was more or less same at all the station and varied between 30.5 to 37.7ppt. pH varied between 7.3 to 8.7. The SST showed positive correlation with salinity, pH, chlorophyll and PO4 ($p < 0.01$) and the salinity was positively correlated with chlorophyll, DO and PO4. Chlorophyll varied between 0-3.4 mg m^{-3} and the mean value was more or less same at 5, 10 and 15 meter depth during full moon periods. Not much variation was noticed in GPP between stations. NPP was comparatively higher at 5 meter depth. Nitrite and phosphate concentrations were comparatively higher in the new moon samples at all the stations. The nitrite was higher at 20 meter depth, phosphate at 10 meter depth, silicate at 15 meter depth. There was a gradation noticed in the transparency with respect to the depth of the stations. The transparency was lowest (0.5 meter) at 5 meter depth to the highest of 12m at 20 meter depth. The transparency showed negative correlation with salinity and chlorophyll and a positive correlation with DO ($p < 0.01$). The studies indicated the congregation of zooplankton more towards 15 meter depth and the dominance of major groups during the new moon periods confirmed the photophobic behavior of zooplankton.

Aggregation and formation of small mounds of tube dwelling polychaetes as indicator of high anthropogenic interactions in Cochin Estuary

Asha, C.V.*, Retina I Cleetus, P. S. Suson and S. Bijoy Nandan
School of Marine Sciences, Cochin University of Science and Technology, Lake Side Campus, Kochi 682 016, Kerala, India. Email: ashakankol@gmail.com

Polychaetes are the most abundant taxon in benthic communities and are one of the best indicators of environmental disturbance, since this taxon contains both sensitive and tolerant species. The effect of stress was easier to measure by utilizing the multispecies assemblages and examining changes in abundance of species. Sewage containing high organic material and other pollutants such as heavy metals and pesticides associated with anthropogenic activities badly affect the polychaete species diversity and its community. Massive polychaete aggregation zone was selected for the study. Aroor, southern part of Cochin estuary was selected for the study. This zone was highly influenced with discharges from shellfish processing industry, land drainages and sewage wastes from Kochi metro city. Bottom water quality and sediment characteristics were observed from March 2011 to February 2012. Samples of macrobenthic fauna were collected using a standard van Veen grab having an area of 0.04 m^2. Polychaetes were microscopically identified to the lowest taxonomic (species) level using standard references.

Average depth of the study area was 7.96 m. Annual average of bottom water and sediment pH was 7.55 and 6.83 respectively. Bottom water temperature showed an annual average of 30.21°C. Average value of bottom water dissolved oxygen and salinity was 7.4mg/l and 11.32ppt respectively.The annual average of organic carbon content of sediment was 2.89%. Sediment texture analyses indicated that majority of the time clayey- silt was observed. Polychaetes formed the abundant group (4229 no/m^2) followed by bivalves (3359no/m^2) and crustaceans (578no/m^2). The study area marked with dense aggregation of tube building polychaete genus *Diopatra* along with massive bed of bivalve *Musculista* sp. Genus *Diopatra* was considered as ecosystem engineers of marine intertidal sediments in the world. This polychaete constructs vertically oriented tubes which display a range of complexity from well-developed inner linings and outer part bound with shell pieces and debris etc. and forms small mounds. These mounds are not continuous but patchy in appearance and extending over several meters. These massive structure forms the habitat for several other benthic organisms including isopod, amphipod, prawns, crabs, Gobioid fishes etc. Polychaete density was maximum (20180 no/m^2) in October 2011 and minimum (250 no/m^2) in August 2011 (Fig.1). A total of 11 species of polychaetes were associated with the reef structure in which *Prionospio cirrifera, Lumbrineris* sp., *Parahetero mastustenuis, Glycera alba, Cossura costa, Nephthysoli gobranchia, Polydora flava, Sabellaria* sp., *Ancistrosyllis parva, Nereis* sp. were most abundant. All these species are pollution indicators and are considered as classical indicators of disturbance reacting to organic enrichment. During monsoon season the complexity and stability of reef

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structure was reduced. It may be due to the heavy rainfall associated with fresh water runoff, strong under water current and tidal flushing affects the stability of the reef structure. Due to high growth rate, reproductive behaviour (opportunistic species) and availability of high organic matter in the sediment activated the formation of massive reef structure during other seasons. Consequently a community has developed around the *Diopatra* tubes taking advantage of these resources. Similar situation was observed in the current study.

Fig. 1. Monthly variation in numerical abundance of polychaetes (no/m^2) during March 2011-February 2012 in Cochin Estuary.

The present study shows that the study area was permanently impacted with organic enrichment and the change was confirmed from presence of a mound structure of polychaetes and associated indicator species characteristic of organic pollution.

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Spatio-temporal variation of primary production and related hydrographic parameters in Cochin estuary, southwest coast of India

Thasneem, T. A.*, P. N. Geetha and S. Bijoy Nandan
School of Marine Sciences, Cochin University of Science and Technology, Lake Side Campus, Kochi 682 016, Kerala, India. Email: flubber7599@gmail.com

The Cochin estuary is facing serious environmental stress arising from a variety of anthropocoene activities like land use changes, waste disposal, over exploitation of resources, coastal erosion, siltation, developmental projects, tourist density, fishing intensity, coastal engineering activities and sand and shell mining activities etc. Over 50% of the estuary is lost due to various human activities. It is assumed that these activities will significantly affect the production and related hydrographical parameters of the estuary. Primary production at nine stations has been investigated for twenty four months from June 2009 to May 2011 period. The study was organised to estimate the primary productivity parameters and related hydrographical parameters (temperature, salinity, pH, dissolved oxygen and turbidity, nitrite, nitrate, phosphate, silicate and ammonia).

The primary production was measured by the light and dark bottle method and chlorophyll estimation. The annual GPP was higher during 2010-11 (4.77 gC /m^3/day) as compared to 2009-10 (2.25 gC /m^3/day) period. The NPP was higher in the northern zone (1.92 gC /m^3/day) and low in the middle zone of the estuary (1.45 gC /m^3/day). The backwater was found to be most productive during monsoon season and least productive during the pre-monsoon season. The ANOVA of GPP and NPP showed 1% level of significance between months (F=16.876, F=4.247), whereas NPP showed 5% significance between station (F=2.212) and

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between surface and bottom waters (F=4.288).Primary productivity values were higher as compared to the earlier observations that may be due to the increased anthropogenic activities in the estuary.

The mean chlorophyll a in the nine stations in the estuary was 11.24 mg/m³. Relatively high value of chlorophyll a' was observed during post monsoon period (15.08 mg/m³) and decreased to an average 4.78 mg/m3 during the monsoon season. The mean annual value of chlorophyll a' was high during 2009-10 (11.74 mg/m³) as compared to 2010-11 (10.75 mg/m³) period. The chlorophyll a' recorded the highest in the northern zone of the estuary (12.69 mg/m³) and lowest in the middle zone (9.71 mg/m³) of the estuary. The mean monthly total chlorophyll in the estuary ranged from 0.23 mg/m³ to 101.59 mg/m³. The chlorophyll b/a ratio and c/a ratios obtained were greater than one during the monsoon season. It may be due to the abundance of detritus in the water column during monsoon.

The average carotenoid values of Cochin estuary was 9.34 MSPU/m³. In the present study the carotenoid values ranged from 0.07 MSPU/m³ to 51.53 MSPU/m³. The phaeo-phytin recorded the peak value during the post monsoon season. The ANOVA of Chlorophyll a', Chlorophyll b' and Chlorophyll c' showed 1% level of significance between months and stations. Productivity variations with space and time and relationship with physicochemical parameters have been statistically determined. Pearson correlation co-efficient showed that water temperature, turbidity, dissolved oxygen and nitrate had significant influence on the rates of production. Chlorophyll a showed a strong positive correlation with dissolved oxygen, nitrate and net primary production. The MDS ordination of station wise primary production and related hydrographical parameters showed that St.2 and 3; St.6 and 7 are very much similar to each other. The need for continuous monitoring of environmental parameters is recommended for long-term ecosystem management and conservation objectives.

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The fish gill and fin: Site of action for toxic effect of environmental pollutants

Sherly Williams, E., V. Lekshmi Priya and l. Razeena Karim*
Department of zoology, Fatima Mata National College, Kollam, Kerala, India.
Email: razeenashibili@rediffmail.com

Heavy metals are very toxic because, as ions or in compound forms, they are soluble in water and may be readily absorbed by aquatic organisms. Fishes have been considered as good indicators for heavy metal contamination. Two commercially important fin fishes (*Etroplus* and *Mugil* species) of Ashtamudi lake were selected from two different sites. Elemental analysis (zinc, copper, lead, chromium and cadmium) were done seasonally for water and sediment samples from both sites. Seasonal collections of fishes were also made for gross morphological study of the fin and gill by SEM.The results of elemental analysis of water and sediment

samples from both the sites during pre monsoon, monsoon and post monsoon season from March 2013 to February 2014 revealed the presence of heavy metals (Table 1). In the present study all the heavy metals were found to be accumulated more in the sediment samples of both sites. When seasons are compared the pre-monsoon season showed higher values for heavy metals whereas lower values were shown in monsoon season. When sites were compared both the sites showed more of less same values. The accumulation of heavy metal were in the order of Cr>Cu>Zn>Pd> Cd.

Table 1. Concentration of heavy metals from two sites of Ashtamudi lake

Site	Sample	Cadmium (mg/L)			Chromium (mg/L)			Copper (mg/L)			Lead (mg/L)			Zinc (mg/L)		
		Pre-M	M	Post-M	Pre-M	M	Post-M	Pre-M	M	Post-M	Pre-M	M	Post-M	Pre-M	M	Post-M
1	Water	BDL	BDL	BDL	0.13	BDL	0.01	0.11	BDL	BDL	BDL	BDL	BDL	0.21	0.06	0.06
	Sediment	0.003	BDL	0.002	0.96	0.70	0.64	0.86	0.47	0.47	0.21	0.12	0.19	0.86	0.35	0.47
2	Water	BDL	BDL	BDL	0.06	BDL	0.01	0.19	BDL	BDL	BDL	BDL	BDL	0.13	0.02	0.03
	Sediment	0.006	BDL	0.003	0.98	0.43	0.86	1.26	0.18	0.87	0.08	0.09	0.07	1.10	0.33	0.27

A number of morphological changes were detected in the gills and the fins of the fishes studied when analysed through SEM. The gross structure of normal gills found to consist of gill arch, gill rakers and gill filaments (Figs. 1, 2). Arising from the gill arch are a number of gill filaments which are arranged in a single row and are equidistant from each other giving it a leaf like structure. The secondary lamella was also observed to be projecting at right angles to the long axis of the filaments, each lamellae lying parallel to the adjacent lamellae. A number of gill rakers were observed to radiate from both sides of the gill arch on the opposite sides of the gill filament; the inner sides of the rakers were equipped with minute projections. But the SEM analysis of present study showed the clubbing of the ends of the secondary lamellae, fusion of adjacent secondary gill lamellae and necrosis in the primary lamellae, epithelial lifting, necrosis and curling of secondary lamellae were well marked in many samples. Gill of fishes also showed gill epithelium disorientation, hypertrophy and hyperplasia of epithelial cells, fusion of gill lamellae and decrease in the number of mucus cells. Fusion of secondary
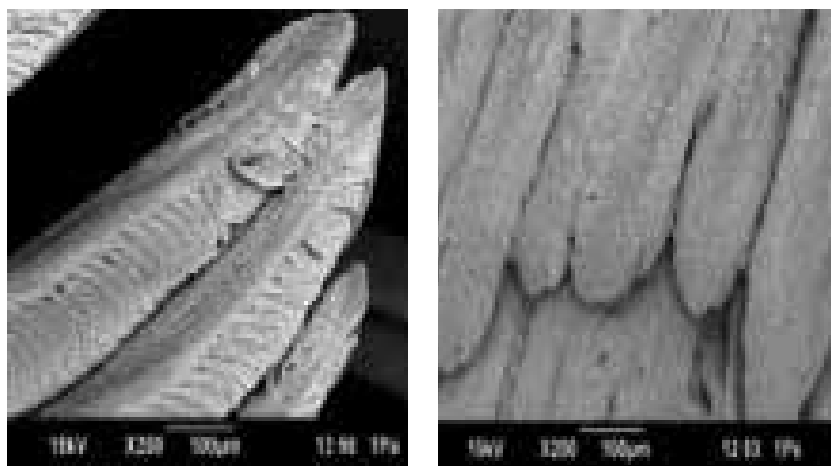
Fig 1 &2. Gross structure of normal gills

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lamellae and vasoconstriction were also noticed in the sample of *Mugil* species during the present study. Vasoconstriction, proliferation and hypertrophy of chloride cells and mucus cells, curling and abnormal elongation of the secondary lamellae, severe inter-epithelial oedema and deformed pillar system were noticed in the gill of *Etroplus*.

Examination of normal fins under SEM revealed a smooth distal edge, whilst the surface of the fin consisted of alternating smooth and corrugated areas of epithelium and the smooth areas were situated over the fin rays. The surface of the fin was covered with normal epithelium. Examination of a number of sections suggested that there was a progressive thinning of the epithelium towards the distal fin. Present study revealed clear cut white depositions in the fins of fishes and this may be due to the combined effect of heavy metals. The end of fin filaments of fishes were more affected due to heavy metal accumulation especially the fins of *Mugil*. If the anthropogenic activities in the lake such as dumping of solid waste, discharge of industrial effluents, leachate etc, persist, or are continued in higher proportion, the accumulation of elements such as lead and cadmium can lead to heavy metal toxicity in aquatic organisms. Therefore, prevention of polluting the lake along with regular monitoring of heavy metals and its impact on its inhabitants are necessary to save the fish diversity of Ashtamudi Lake, the Ramsar site.

Spatial variation of size fractionated chlorophyll *a* in coastal waters of southeastern Arabian Sea

Minu, P.*, V. P. Souda, U. Sumith, P. MAshraf, L. Edwin and B. Meenakumari
Central Institute of Fisheries Technology, Matsyapuri P.O., Kochi 682 029, Kerala, India.
Email: minoos29@yahoo.co.in

Phytoplankton size structure influences the underwater light field and determines the fate of carbon in a pelagic food chain. They are the result of success of certain community to survive and grow in an unstable environment controlled by varying physical and chemical characteristics. Hence it is very important to understand the community structure of phytoplankton size fractions. Spatial and vertical variations of size fractionated chlorophyll a concentration (chl *a*) were investigated at 8 stations from May 2013 to April 2014 in order to understand the relationship between environmental parameters and phytoplankton size distribution in coastal waters of southeastern Arabian Sea. The growth of different phytoplankton was mainly controlled by nutrient concentrations in the area. Increased silicate concentration influenced the growth of microphytoplankton while nanopytoplankton by increased nitrate and phosphate concentration. High ammonium concentration enhanced the growth of picophytoplankton. The study also showed a clear variation from a dominant diatom to dinoflagellate and cyanophyte community. The study identified abundance of microphytoplankton around 10 m depth, nanophytoplankton surface to 5 m depth and picophytoplankton in 10-20 m water column. The regression analysis between total chla concentration and sum

of chla concentration in different size fractions showed good agreement ($R^2=0.87$; N=81). Pre-showers and extended southwest monsoon along with variation in nutrient concentrations in the area during the study period are responsible forvariation in size fractionated chlorophyll, absorption by phytoplankton and its numerical density. These data will provide an insight into the chemical factors that control the production cycle in this neritic system. General patterns in the size structure of the phytoplankton community can also be used in improving size fraction algorithms for various societal applications of remote sensing.

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ICT strategy to reduce the impact of the climate change in marine fisheries of India

Veerendra Veer Singh*, Arun Pande, Dineshkumar Singh, Sujit Shinde, Rahul Sharma, Srinivasu Pappula
Central Marine Fisheries Research Institute,Mumbai Research Centre, Versova, Mumbai 400 061, Maharashtra, India. Email: veerendraveersingh@gmail.com

Warmer ocean and melting glacier due to climate change can lead to increase in the sea temperature. INCOIS Hyderabad developed fish shoals prediction model based on the remote sensing data received from NOAA satellites, sea surface temperature and the presence of phytoplankton. The challenge was to effectively communicate the outcome of this model to the fishermen and the coastal regions. CMFRI, Mumbai and TCS joined hands with INCOIS to conceptualize a pilot to develop local language mobile applications to relay this information in real-time to the fishermen.

Information availability in local language and image form helped fishermen to see the potential fishing zones (PFZ) near to them. This helped them plan the amount of the diesel required, the ice and the labour. Such planning helped them use the optimum quantity of the diesel. Also, they started escaping venturing in to the sea when the PFZ is not in their region or the sea is turbulent as displayed by the wind speed and direction images. This "self-imposed ban" helped in a reduction in the quantity of diesel consumption and hence the adverse impact on the environment due to carbon emission. Kimbahune (2013) analysed the pilot results from the 13 societies and found that those fishermen who followed the service, their fishing yield increased on an average by 30% whereas it reduced the cost and the diesel consumption by 30-40%.

The service was expanded to entire district covering 56 societies in a Public Private Partnership (PPP) model with Tata Teleservices (DoCoMo) through a business model. The objective is to make this service self-sustainable and grow beyond the pilot duration. This consortium approach is helping to take the research to the sea and to the market. There are challenges associated in terms of improving delivery channel, hand holding fishermen, diversity of the mobile handsets and pricing, which all the consortium partners are collaborating to work on. This approach makes it more sustainable and scalable as each consortia partner is focusing on their strength area such as CMFRI Mumbai has been focusing on the

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ground research and feedback collection, INCOIS in improving the no. of Oceanic services such as Tsunami and high wave warning, TCS in making the platform simpler to use and adding other ICT services and TTSL embedding this offer in their established delivery network.

The services have been started in Ganjam in Odisha district and fishermen used wind speed and direction to monitor Hudhud cyclone progress and take the adaptive measure. The plan is to expand this service to four districts of Maharashtra followed by Gujarat and Andhra Pradesh by 2015

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Carbon sequestration by certain seagrass species of Gulf of Mannar, southeast coast of India

Kaladharan, P.*, P. U. Zacharia, and K. Shanmuganathan
Central Marine Fisheries Research Institute, Kochi 682 018, Kerala, India. Email: kaladharanep@gmail.com

Mangroves, seaweeds, seagrasses and marine phytoplankton collectively contribute to the half of world's carbon fixation and they also account equally for all carbon storage. This report presents carbon sequestration efficiency of five species of seagrasses from the Gulf of Mannar. Light harvested CO_2 fixation rates varied considerably among the species studied, registering maximum of 8.03 kg C/ton wet weight/day for *Halophila ovalis* and a minimum of 1.63 kg C/ton wet weight/day for *Enhalusa coroides*. However their carbon storage in the sediment in the form of rhizome and root wet biomass showed maximum for *Enhalus acoroides* (1.173 kg/ m²) followed by *Cymodocea serrulata* (0.945 kg/m²) and the lowest by *Halophila ovalis* (0.535kg/ m²). As seagrasses are perennial rooted flowering plants and their root/shoot ratio is always higher, CO_2 fixation by leaves and carbon storage by rhizomes and roots greatly help checking the ocean acidification.

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Carbon footprint of marine fishing in Chennai fisheries harbour - LCA analysis

Geetha, R*, Divipala Indira, M. Santhi, K. S. Gupta, Shoba Joe Kizhakudan, and P. U. Zacharia,
Central Marine Fisheries research Institute, Madras Research Centre, 75 Santhome High Road, Chennai 600 028, Tamil Nadu, India. Email:geethaeconomist@rediffmail.com

The present study focuses on carbon-di-oxide emission in mechanized fishing by trawlers and gillnetters and in motorized fishing by various sources viz.,electricity,

diesel, petrol and LPG at three different phases of pre harvest, harvest and post-harvest. Energy emitted from boat construction yards and net manufacturing units were considered under pre-harvest phase, fishing and ice consumption have been included under harvest phase whereas emission from fish distribution and consumption were estimated in post-harvest phase.

Total carbon footprint in CFH during 2012 was 64 million kg CO_2e. Estimated carbon emission per kg of fish and per hour of actual fishing were 1.68 and 92.63 kg CO_2e respectively. Mechanized sector emitted 60.65 million kg CO_2e (94.5 % to total) and motorized sector contributed 3.53 million kg CO_2e. Trawl catch contributed 67 % of carbon footprint (43.13 million kg CO_2e) followed by Multi Day (MD) gillnetters (17.52 million kg CO_2e) in mechanized fishing.

Harvest phase emitted 89.7 % of total carbon followed by post-harvest phase (5.59 million kg CO_2e) and pre harvest phase (1.02 million kg CO_2e). In harvest phase fishing was the major contributor which emitted 85 % of total carbon. Diesel was the key source of emission at harvest phase and contributed 54.5 million kg CO_2e. Trawler emitted 36.22 million kg CO_2e in harvest phase.(Fig 1) Emission in pre-harvest phase was mostly by electricity used (68 %) followed by diesel burnt. In pre harvest phase, mechanized and motorized catches emitted 83.43 and 16.57 % respectively. In post-harvest phase 78 % of carbon was emitted by LPG use and 18.92 % was by diesel burnt. In harvest and post-harvest phases, trawl emission was more (66.49 and 81.4 % to total) where as in pre harvest phase, gillnetters emitted 54 % of total.Emission by motorized fishing was 0.17, 2.85 and 0.51 million kg CO_2e at pre harvest, harvest and post-harvest phases respectively.

Diesel was the major source of carbon footprint which emitted 55.88 million kg CO_2e in Chennai. In LPG carbon emission, 90.8 % (4.34 million kg CO_2e) was emitted while cooking food by fish consumption. Electricity consumption was maximum in harvest phase (50.11 lakh KWh) followed by pre harvest phase (13.25 lakh KWh). Trawl vessel construction consumed 76 % of total electricity used at yards. Mechanized catches consumed 41.44 lakh KWh of electricity and emitted 95.6 % of total electricity carbon footprint at harvest phase. Among all the sources, carbon emission by diesel was very high (87 %) followed by LPG which is 7.45 %. Carbon emission by electricity consumption was very low (5.30 %). (Fig 2) Carbon emission by boat construction, net fabrication, ice consumption, fishing, distribution and consumption was 0.43, 0.59, 2.83, 54.74, 1.13 and 4.45 million kg CO_2e respectively (Table 1).
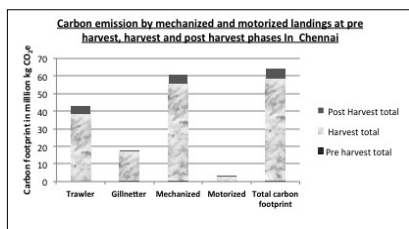
Fig 1:Carbon emission by mechanized and motorized landings at pre harvest, harvest and post-harvest phases In Chennai during 2012
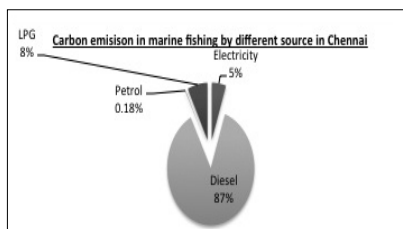
Fig.2: Carbon emission in marine fishing at Chennai fisheries harbour during 2012 (in million kg CO_2e)

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Mechanized and motorized fishing emitted 1.59 and 0.09 kg CO_2e per kg of fish respectively. Gear wise, carbon emission by mechanized trawlers (1.14 kg CO_2e per kg of fish) was recorded high compared to MD gill netters (0.46 kg CO_2e per kg of fish). Harvest phase was the major area of concern in which both mechanized and motorized catches emitted carbon significantly.Shifting from energy intensive techniques and implementing fuel efficiency norms cansignificantly reduce carbon emission for the marine fishing boats operating from Chennai.

Table 1. Carbon emission by different sectors and sources in Chennai Fisheries Harbour during 2012 (in million kg CO2e)

Particulars	Diesel	Electricity	Petrol	LPG	Total
Pre harvest	0.32	0.70			1.02
a) Boat building yards	0.29	0.14			0.43
b) Net manufacturing unit	0.03	0.56			0.59
Harvest	54.50	2.63		0.44	57.57
a) Ice plants	0.20	2.63		0.00	2.83
b) Fishing	54.30			0.44	54.7
Post-harvest	1.06	0.07	0.11	4.34	5.59
a) Distribution	1.06	0.07			1.13
b) Consumption			0.11	4.34	4.45
Total	55.88	3.40	0.11	4.78	64.18

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Geospatial distribution and species diversity in fished taxa along the Indian coast

Sathianandan, T. V.*, K. S. Mohamed, Somy Kuriakose, K. G. Mini, A. P. Dinseshbabu, Grinson George and Sindhu K. Augustine.
Central Marine Fisheries Research Institute, Kochi 682 018, Kerala, India. Email: tvsedpl@gmail.com

There are 1511 marine fish landing centres along the Indian coast where landings by different types of fishing crafts take place throughout the year. Every year nearly 600 to 700 species are landed along the coastal waters of India. When examined for a longer period, the number of species landed is more than 1000. The species diversity along the Indian coast is examined here using individual species wise and fishing zone wise landings data during 2007-2013 generated by the Central Marine Fisheries Research Institute by following a stratified multistage random sampling design, where fishing zones are distinct and non-overlapping geographical regions covering the entire coastline of the country. Average taxonomic distinctness DELTA+ and variation in taxonomic distinctness LAMBDA+ were worked out for each of the 120 fishing zones.

Out of the 936 species landed along the Indian coast during 2007-13, Indian mackerel (*Rastrelliger kanagurta*) and Kingseer (*Scomberomorus commerson*) are

the only two species that were landed in all the 120 fishing zones during the period examined. Quantity wise, the maximum landings during 2007-2013 were 3.77 million tones of oil sardine (*Sardinella longiceps*) and 1.4 million tones of Indian mackerel and the minimum were 16 kg of Fringefin zebra sole (*Zebrias quagga*) and 29 kg and Mozambique large-eye bream (*Watssia mozambica*) respectively. There were 161 species that were landed only in one of the 120 fishing zones. Using information on latitude/longitude pertaining to each of the fishing zones its relationship with DELTA+, LAMBDA+ and alpha diversity were examined. Bray-Curtis dissimilarity matrix were generated for the fishing zones and used for classification of the fishing zones through Multi Dimensional Scaling. The taxonomic distinctness is inferred with respect to the ecological significance of fishing zones studied.

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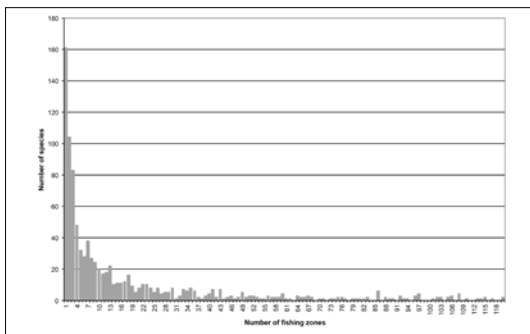
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Seasonal variation of intertidal gastropods of Shirgaon mangroves, Ratnagiri, Maharashtra

Karhale, S. M.*, A. D. Adsul, S. T. Indulkar, R. Pai and S. S. Lokhande
College of Fisheries Shirgaon, (Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth), Ratnagiri 415 629, Maharastra, India. Email: satishraje.patil555@gmail.com

This communication highlights the seasonal variation of gastropods of Shirgaon mangroves of Ratnagiri, Maharashtra from February 2012 to January 2013. Monthly samples were collected from exposed intertidal region of mangroves during the lowest low tide. A total of thirteen macro-faunal species of gastropods were recorded among which, *Cerithidea cingulata* and *Telescopium telescopium* were recorded in all seasons. The density of *C. cingulata* and *T. telescopium* was maximum (126.6667 no.m^{-2}) and (4.7618 no.m^{-2}) during post-monsoon and pre-monsoon season while it was minimum (104.9524 no.m^{-2}) and (2.2857 no.m^{-2}) during pre-monsoon and post-monsoon season respectively. The neretids such as *N. costata* and *N. peloronta* have shown inconsistence occurrence throughout year. The *Nerita crepidulaia* was recorded in all seasons except during late pre-monsoon season while *N. pelornata* and *N. costata* were recorded sporadically. *Nassarius coronatus*, *N. arcularius* and *N. dorsatus* were recorded only once during January,February and March respectively. The *Onchidium* sp. and *Casidula nucleus*

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were recorded during monsoon and post-monsoon period respectively. *Cantharus* sp. was recorded from the late pre-monsoon to early monsoon season. *Nassarius arcularius* was recorded in early pre-monsoon while *Nassarius coronatus* in late post-monsoon. The atmospheric temperature, water temperature, sediment temperature and water salinity were found to be maximum during the pre-monsoon and minimum during the monsoon season.

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Diurnal fluctuation of greenhouse gases emission from *L. vannamei* culture ponds

**Vasanth, M*, M. Muralidhar, R. Saraswathy, J. Syama Dayal, N. Lalitha,
P. Kumararaja, M. Jayanthi, A. Nagavel and J. Shanmugakarthik.**
Central Institute of Brackishwater Aquaculture, 75, Santhome High Road, Chennai 600 028, Tamil Nadu, India. Email: mvasanth84@gmail.com

Climate change, a consequence of excessive emissions of greenhouse gases (GHGs) from fossil fuel combustion in energy generation, transport and industry, deforestation and intensive agriculture is no longer simply a potential threat but unavoidable. Among the agriculture sectors, aquaculture has contributed little to the causes of climate change but will be first amongst vulnerable agriculture system to be disproportionately affected by its impacts. While data regarding the GHGs emission from the paddy and livestock are available, studies related to GHGs emission from aquaculture systems are scanty. The Institute has standardized the methodology for the collection of GHGs from aquaculture ponds and quantified the global warming potential from shrimp culture systems based on the monthly GHGs emission values. The species, intensity of culture, type and quantity of inputs applied clearly indicated the contribution of aquaculture to global warming.

The objective of the present study is to investigate the diurnal fluctuation in GHGs (CO_2, CH_4 & N_2O) emission in the *Litopenaeus vannamei* culture ponds (stocking density of 44 nos./m^2) located in Katur, Tamil Nadu during October 2013 to January 2014. The GHGs were sampled from the surface of pond water in tedlar bags using air pump at four hourly intervals, starting at 8 hrs for 24 hour cycle at different days of culture (28, 57, 83 and 116), using a free floating cylindrical acrylic chamber with outlets connected by silicon tubing via three way stopcock. In situ water measurements were done for temperature, salinity, pH and dissolved oxygen using portable water quality analyzer at each sampling. The tedlar bags and water samples were transported to the laboratory in ice cool box for immediate analysis by GHG analyzer and for general water parameters.

Results indicated that the fluxes of CO_2, CH_4 and N_2O across the water-air interface demonstrated an obvious diurnal variation. The emission concentration of CO_2, CH_4 and N_2O increased with increase in the days of culture and the values ranged between 395 to 704 ppm (496$\pm$ 89ppm), 1.72 to 3.02 ppm (2.24$\pm$ 0.44ppm) and 318 to 335 ppb (328$\pm$ 4.5ppb), respectively. CH_4 emissions were high at

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4hrs early in the morning due to anoxic conditions, decreased at 8hrs and again increased during day time as a function of temperature. A gradual increase was observed with CO_2 emission from 8hrs during the day time as a function of temperature and higher value was recorded at 4hrs in the morning. High value of N_2O were recorded during the day time compared to night.

Among the water quality parameters, dissolved oxygen content (2.6 ppm at 4 hrs and 9.1 ppm at 12 hrs) and pH (7.02 at 4hrs and 7.87 at 16hrs) exhibited distinct diurnal variation. The concentration of unionized ammonia and nitrite-N ranged between 0.0001 ppm to 0.05 ppm and 0.04 ppm to 0.28 ppm, respectively during the 24hr cycle. CH_4 and CO_2 emissions were positively correlated ($p \leq 0.05$) and high value of these two GHGs were associated with high values of ammonia and nitrite and low dissolved oxygen.

Implementation of better management practices (BMPs) such as optimum stocking density, pond bottom management and providing proper aeration to maintain optimum dissolved oxygen level could minimize emission of GHGs from shrimp culture ponds.

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A spatio-temporal analysis of the select climate variables In the Indian Exclusive Economic Zone

Ambrose, T. V., K. A. John Bose*, J. Jayasankar, V. Kripa and P. U. Zacharia
Central Marine Fisheries Research Institute, Kochi 682 018, Kerala, India.
Email: johnalexplymouth@yahoo.in

Over the past six decades substantial changes have been observed in the global climate. According to IPCC reports, the magnitude of the climate variables vary greatly from region to region and its effects on the marine ecosystems vary as well. The current study focused on the climate parameters of the Indian Exclusive Economic Zone (IEEZ) during the last fifty five years (1960 - 2014) and are described in Table. 1.The datasets on the climate variables of the Indian EEZ was accessed from the International Comprehensive Ocean Atmospheric Data Set (ICOADS) and analysed using the R software. The IEEZ was divided into six regions such as South West EEZ (SWEEZ), South East EEZ (SEEEZ), North East EEZ (NEEEZ), North West EEZ (NWEEZ), Lakshadweep EEZ (LAKEEZ) and Andaman EEZ (ANEEEZ) for assessing the spatio-temporal variations. Our spatial analysis of Air Temperature (AT) revealed that SEEEZ region had the highest average value of 28.27 °C during 1960-2014. On the other hand NEEEZ showed lowest average value of 27.67°C (Fig. 1-A). Similarly, monthly average figures of AT were analysed and it clearly indicated that was the lowest fluctuations in the month of October and wide range of fluctuations were characterised in the month of January (Fig. 1-B). When average AT of the IEEZ were analysed over the regions, it was observed that the variations were less in SEEEZ and SWEEZ when compared with the NEEZ and NWEEZ (Fig. 1-B). All the other select climate parameters will be discussed in the paper in detail.

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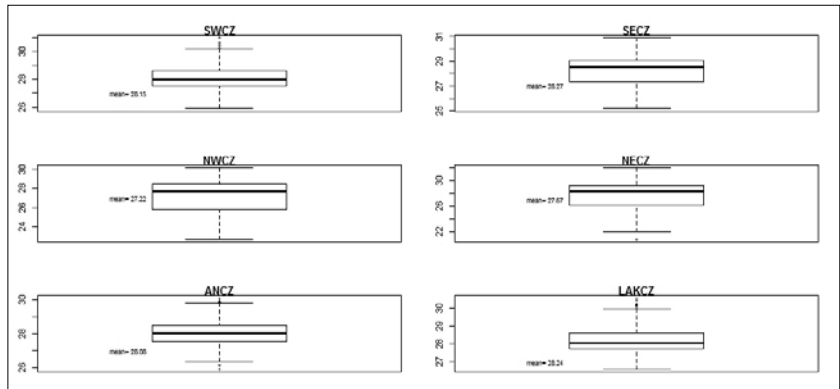
Fig..1-A. Regional Air Temperature (°C) of IEEZ (1960-2014)
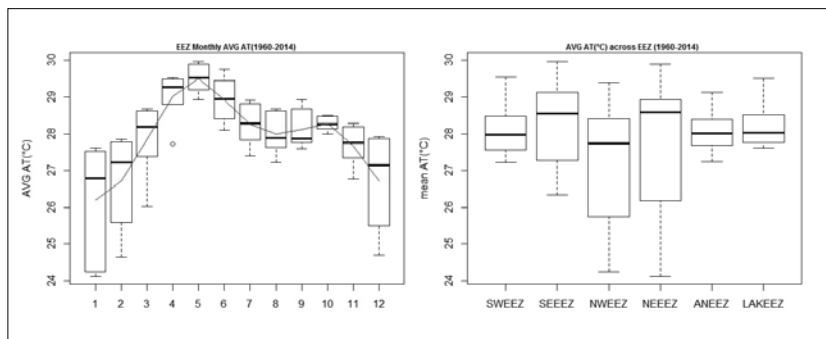
Fig.1-B. Monthly and regional average of Air Temperature (°C) of IEEZ (1960-2014).

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Opportunistic sighting and behavioral pattern of cetaceans in the Indian EEZ and the contiguous seas

Abhilash, K. S.*, K. K. Sajikumar, R. Jeyabaskaran, N. Raghesh, V. Kripa and K. S. Mohamed
Central Marine Fisheries Research Institute, Kochi 682 018, Kerala, India. Email: abhilashks79@gmail.com

Marine mammals of Indian EEZ and the contiguous seas have been documented by Central Marine Fisheries Research Institute, India for over a period of 10 years. 25 species of cetaceans, which include baleen whales, toothed whales, dolphins and single species of sirenian are known to occur in India. This study was based on opportunistic sightings onboard *FORV Sagar Sampada* along with the other oceanographic research cruises. Published pictures of whole animals, size of spouts, shape of dorsal fin and caudal flukes of different species were used to identify the cetaceans sighted. The study area included the coastal, continental shelf and oceanic waters of the Indian EEZ and the Sri Lankan Sea. The surveyed area extended between 5°-23°N latitude and 66°-95°E longitude with depth range of 20-5000 m.

Table-1. Climate variables and IEEZ

Region	Sub region	LAT1	LAT2	LON1	LON2	Spatial resolution	Time span (monthly)	Climate variables*							
								AT(A)	SST(S)	SLP(P)	TC(C)	SH(Q)	U	V	W
NWEEZ	NW1	16.0	20.0	70.0	73.0	1°x1°	1960-2014	√	√	√	√	√	√	√	√
	NW2	20.1	24.0	65.0	73.0	1°x1°	1960 2014	√	√	√	√	√	√	√	√
SWEEZ	SW1	8.0	12.0	74.0	77.0	1°x1°	1960 -2014	√	√	√	√	√	√	√	√
	SW2	12.1	16.0	72.0	75.0	1°x1°	1960 -2014	√	√	√	√	√	√	√	√
SEEEZ	SE1	8.0	16.0	77.0	86.0	1°x1°	1960 -2014	√	√	√	√	√	√	√	√
	SE2	16.1	19.0	81.0	89.0	1°x1°	1960 -2014	√	√	√	√	√	√	√	√
NEEEZ	NEEEZ	19.0	22.0	85.0	89.0	1°x1°	1960 -2014	√	√	√	√	√	√	√	√
LAKEEZ	LAKEEZ	8.0	12.0	71.0	74.0	1°x1°	1960 -2014	√	√	√	√	√	√	√	√
ANEEZ	ANEEZ	6.0	14.0	91.0	95.0	1°x1°	1960 -2014	√	√	√	√	√	√	√	√
Climate parameters units data:-International Comprehensive Ocean-Atmosphere Data Set (ICOADS)								0.01°C	0.01°C	0.01 hpa	0.1 okta	0.01 g/kg	0.01 m/s	0.01 m/s	0.01 m/s

*AT(A)-Air temperature; SST(S)-Sea Surface Temperature; SLP(P)-Sea Level Pressure; TC(C)-Total Cloudiness; SH(Q)-Specific Humidity; U-Vector wind Eastward component; V-Vector wind Northward component; W-Scalar wind; LAT-latitude; LON-longitude; NWEEZ-North West Exclusive Economic Zone; SWEEZ-South West Exclusive Economic Zone ; SEEEZ-South East Exclusive Economic Zone; NEEEZ-North East Exclusive Economic Zone; LAKEEZ-Lakshadweep Exclusive Economic Zone; ANEEZ-Andaman and Nicobar Islands Exclusive Economic Zone

Cetacean family observed during the study includes Balaenopteridae, Physeteridae, Delphinidae and Ziphiidae. During the sighting of a cetacean it has been observed that they exhibit various behavioral actions. This article is an attempt to document some of the behavioral features observed during sighting of a dolphin or a whale. These include breaching, foraging, bow riding, leaping, surfacing the water, spinning, fluking and aerial behavior. This attempted study is only a fractional part for more future studies leading to novel insight into the behavior of Cetaceans in the Indian EEZ.

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Effect of adverse factors on the density and distribution of marine macroalgae along Indian coasts

Chennubhotla, V. S. K.*, K. S. Rao and N. Kaliaperumal
Central Marine Fisheries Research Institute, Kochi 682 018, Kerala, India.
Email:chennubhotlavsk@gmail.com

The density and distribution of marine macroalgal resources of Indian waters are affected since recent years due to a number of factors-over exploitation, sediment deposition, discharge of effluents, changes in the environmental factors, water temperature, light intensity, tidal waves, cyclones and consequence of bottom trawling for fishes. As a result there is decrease in algal production in many areas. On the other hand there is rising demand for the phycocolloids such as agar, algin, carrageenan and others. In this context there is urgent need for conservation and better exploitation of the resources.

Regulation of exploitation, control of pollution by domestic and industrial

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effluents, transplantation of algae of economic importance in other coastal areas with favorable environmental conditions for growth, conducting mass culture are proposed as measures to overcome the damage to natural algal stock to enable conservation and sustained production. Attempts have to be made to assess the distribution of marine algae in deeper waters using remote sensing techniques.

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Distribution and foraging behaviour of seabirds in southwest coast of India

Jeyabaskaran, R.*, Jishnu Mohan, Abbas A. Muhammed, K. S. Abhilash, P. G. Vishnu, L. R. Khambadkar and V. Kripa
Central Marine Fisheries Research Institute, Kochi 682 018, Kerala, India. Email: jbcmfri@gmail.com

Seabirds are the apex predators in the marine ecosystem. So far 346 species of sea belong to 9 families were reported in the world among 9000 birds of 156 bird families. Seabirds are the indicators of fish shoal for fishers and play an important role in recycling nutrients in pelagic ecosystem. Research on seabirds of India is very limited and most of the information is available on shore birds. Extensive field surveys were conducted from September 2013 to October 2014 to study the seabirds of southwest coast of India. The results showed that 23 species of seabirds belongs to 15 genera of 8 families were present in the area. Among these Boobies, Cormorants, Shear waters, Petrels, Gulls, Terns, Noddies and Skuas abundance were estimated using band transect method. The Brown-headed gull *Larus brunnicephalus* were abundant in January and Flesh-footed shear water *Ardenna corneipes* were dominant during June. The maximum 7500 numbers of Flesh-footed shearwaters were observed on 26th June 2014. The seabird diversity was more during upwelling period. The food preference and foraging behavior of seabirds in India has not been studied so far except for Pelicans and Cormorants. The present study showed that oil sardine was the most preferred food for the shear waters and the next preference was anchovies. It fed only live fish and not at all eating dead fish. The flesh-footed shearwaters distribution and abundance was directly correlated to the occurrence of oil sardine shoal. When ship passes through the oil sardine shoal, one or two shearwater sees it and makes high pitched squeal. Immediately, all other shearwaters flock to, that area come close to the ship and heavy competition was observed among them in scavenging fish. Most of the terns preferred to feed on white shrimp *Penaeus indicus* and *Metapenaeus dobsoni*. The foraging behaviours like scavenging, surface pecking, skimming, dipping, pursuit plunging, surface seizing, pursuit diving of different seabird species with photographic evidence are discussed in the paper for the first time in India.

Distribution and abundance of epibiont protista from Ayiramthengu mangrove ecosystem of Kerala coast

Chithra, P.* and R. Sunil Kumar
P.G and Research Department of Zoology, Catholicate College, Pathanamthitta 689 645, Kerala, India.
Email: chithraprotozoa@gmail.com

The present study evaluates the distribution and abundance of epibiont protists from the prop root of mangrove *Rhizophora apiculata* and also from the submerged litters found in and around the base of the mangrove plants. Sampling was done on 20th July 2014. Epibiont samples were taken by scraping 1 cm^2 patch of moist film from the prop roots and litters. It was preserved in a sterile bottle containing 3% formalin and diluted to 5 ml. The samples were then passed through silver carbonate technique for identification. Sedgwick rafter counter was used for the enumeration of epibionts. The environmental parameters of the water such as temperature, dissolved oxygen, salinity, pH, conductivity, phosphate, nitrate and sulphate were determined. The original photograph of the organism was also taken.

The protists belonging to the two groups, ciliates and flagellates were encountered in the present study. A total of 15 genera were identified of which 12 genera were ciliates (*Vorticella, Thuricola, Zoothamnium, Vaginicola, Rhabdostyla, Cothurnia, Pyxicola, Stentor, Paramecium, Euplotes, Epistylis* and *Prorodon*) and the remaining 3 being flagellates (Acineta, Peranema and Euglena). Maximum density and abundance of organisms were found in litters rather than prop roots. Total population density of ciliates in litters and roots were 347ml and 567ml respectively while the density of flagellates was comparatively low 22 ml in litters and 284/ml in roots. The most dominant ciliate in root was *Vorticella* (50.79 %) and least was *Vaginicola* (0.17%). *Acineta* represent the most dominant flagellates in roots (77.46 %) and the minimum was *Euglena* (1.40 %). *Zoothamnium* was the dominant ciliate in litters (44.66%) and least was *Rhabdostyla* (0.29 %). *Peranema* was the most dominant flagellates in litters (72.72 %). Most of the species were common in roots and litters except *Pyxicola* and *Prorodon* which were found only in litters.

Climate change impacts better recruitment, extension of spread and abundance of *Sardinella longiceps* in northern Arabian Sea

Zacharia, P. U., Somy Kuriakose, Rekha J. Nair, J. Jayasankar, S. Dineshkumar, T. H. Sajna and Grinson George*

Central Marine Fisheries Research Institute, Kochi 682 018, Kerala, India. Email: grinsongeorge@gmail.com

Inter-annual variability in the abundance of *Sardinella longiceps* is induced by global warming which in turn affected its assemblage and distribution in northern Indian Ocean. There are indications of change in productivity pattern and temperature in the coastal waters. Primary productivity (PP) (55% increase in eutrophic waters) and average sea surface temperature (SST) in northern Arabian Sea (1.2˚C increase in 100 years) showed an increase during the last decade. The enhanced productivity, due to increased upwelling in eastern Indian Ocean and stratification breakage by extreme events such as cyclone, had impacts on the *S. longiceps* fishery.

The contribution of oil sardine during 1985 in the Kerala-Konkan coast was 13.3% of the total fish landings in India and 95% of the total oil-sardine landings. However, Maharashtra and Gujarat which contributed only 1.5% to the total sardine fishery in 1985 increased to 5.5% in 2007. Landings of oil sardine in the northwest region increased by 31,548 tonnes (t) during the period 1985-2012. However, the landings in the southwest coast also increased from 1,14,105 t in 1985 to 5,61,378 t in 2012. Similarly, landings along the Tamilnadu and Andhra Pradesh which were 2.6% only in 1985 increased to 27% in 2009 and 13% in 2012. Thus, over a period, landings of oil sardine increased by 4,40,803 t during 1985-2012.

During the last 100 years, SST increased by 1.3˚C and 0.8˚C along the southeast and southwest coasts respectively. Congenial productivity and temperature conditions resulted in the enhanced potential and recruitment success of Indian oil sardine population in the area thereby increasing the production. The increase in production of oil-sardine all along the Indian coastline during 1985-2012 is a pointer to the beneficial effects of increase in PP and SST to small pelagics.

The increased SST and primary production has caused a horizontal expansion in the area of oil sardine without affecting the catches in initial areas. Though the major recruitment and abundance of oil-sardine is along the Malabar upwelling regions, their spread in the entire Indian coastal waters may be attributed to the increased temperature and productivity in other regions.

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Spatial variation of primary productivity and abundance of phytoplankton at selected stations along Cochin coastal waters

Soumya Krishnankutty*, Jesmi Yousuf, T. Jabir, C. Ajith Joseph, P. D. Vincent, M. Nashad, P.S. Vishnu, A.V. Saramma and A. A. Mohamed Hatha

Department of Marine Biology, Microbiology and Biochemistry, School of Marine Sciences, Cochin University of Science and Technology, Kochi 682 016, Kerala, India. Email: soumya.krishnankutty@gmail.com

Primary production is the conversion of energy in the form of electromagnetic radiation into stored chemical energy by producers. Phytoplanktons, the drifting photosynthetic factories are the major primary producers of the ocean and initiate the food chain. The purpose of this work was to find out the spatial variation of primary productivity at the selected stations of Cochin estuary and coastal waters and the influence of various physicochemical parameters on primary productivity. Primary productivity of the selected stations of the Cochin estuary and coastal waters was studied by Winkler's light and dark oxygen bottle method. Nutrient parameters such as Ammonia, Nitrite, Nitrate, Phosphate and Silicate of water samples were also analyzed. While the surface temperature varied from 27.8°C and 31.4°C at different stations, salinity showed a significant variation ranging from 15 ppt - 35.5 ppt. Ammonia concentration ranged between 1.71 mg/l - 14.31 mg/l, Nitrite concentration from 0.02 mg/ l - 1.26 mg/l, Nitrate concentration from 1.15 mg/l - 3.45 mg/l, and Phosphate concentration from 0.37mg/l - 19.43 mg/l. Silicate showed a large variation ranging from 3.48 mg/l to 34.98 mg/l. The gross primary productivity range in between 0.384 mgC/l/h - 1.44 mgC/l/h, with higher productivity at Station No. 3 and minimum productivity at Station No. 7. Chlorophyll *a* showed the maximum concentration from Station No. 9 and minimum concentration from Station No. 5. (Fig.1) While maximum abundance of phytoplankton was observed at Station No. 4 (Fig.2), which is attributed to dominance of a particular Genus *Skeletonema* least abundance was observed at Station No. 10. The study throws light on primary productivity of this area which is important to predict the fisheries potential and other potential sources of that area.
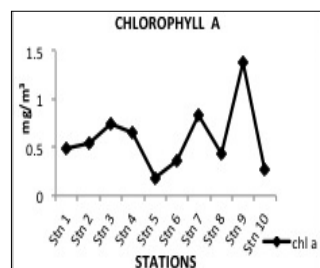
Fig. 1 Chlorophyll a of selected stations of Cochin
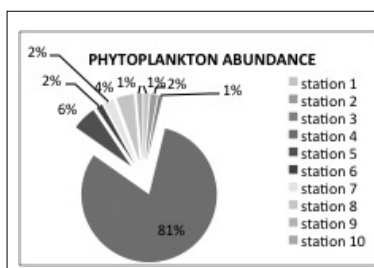
Fig. 2 Phytoplankton abundance at selected stations off Cochin
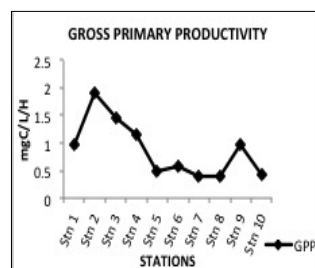
Fig. 3 Gross Primary Productivity of selected stations of Cochin

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Species diversity of Cyanobacteria in Cochin estuary and nearshore waters

Sincy Joseph* and A.V. Saramma
Department of Botany, St. Stephens College, Uzhavoor, Kottayam, Kerala, India.
Email: sincy.j@ststephens.net.in

In view of the great biotechnological potential of Cyanobacteria and the abundance of their biomass in the marine environment of the world in general, and the Indian subcontinent in particular, an extensive study has been carried out on their qualitative and quantitative distribution of Cyanobacteria along Cochin estuary. Cochin backwater system is the largest estuarine system on the southwest coast of India, which forms a permanent part of Vembanadu Lake. It extends between Thanneermukkam bund at the south and Azhikode at the north (9°30'-10°12'N and 76°10'- 76°29'E) and extends over an estimated length of -60kms and an area of - 21,050 ha. In order to evaluate seasonal variation in species diversity and distribution, monthly collection of water and sediment samples from Cochin backwaters and near-shore areas were conducted from April 2002 to March 2003. In the second year of the study (April 2003 to March 2004), sampling was held bimonthly. Determination of the effects of physico-chemical factors on Cyanobacterial diversity was also done. A total number of 75 species of Cyanobacteria from 24 genera across 7 families and 4 orders of the class Cyanophyceae were recorded. Thirty one of these were unicellular colonial forms, 43 nonheterocystous filamentous forms and two were heterocystous filamentous forms. The predominant species observed were *Chroococcus turgidus, Chroococcus tenax, Synechococcus elongatus, Synechocystis salina, Oscillatoria foreaui, Oscillatoria remyii, Oscillatoria pseudogeminata, Oscillatoria subtillissima, Oscillatoria willei, Phormidium purpurescens and Phormidium tenue*. Atmospheric temperature, salinity and euphotic depth had a positive correlation with the Cyanobacterial density, whereas, nutrients had a negative impact when they were in excess. Pre-monsoon season was characterised by high density of organisms, whereas, cell count was very low during monsoon season. From the results, it is evident that the ecological conditions of Cochin Estuary support a rich Cyanobacterial wealth.

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Vulnerability of fisher folk to climate change - A case study in coastal Karnataka

Swathi Lekshmi, P. S*, Shyam Salim and B. Johnson
Central Marine Fisheries Research institute, Mangalore Research Centre, Hoige Bazar, Mangalore 575 001, Karnataka, India. Email: swathi.lekshmi263@gmail.com

Climate change or a change in the statistical distribution of weather parameters over decades is rapidly impacting fisheries both marine and freshwater, fish reproduction, fish growth and migration and in turn is impacting the livelihoods of millions of fishers the world over. Throughout the world, fisher folk are poorly informed of climate change and its consequences that would impact the livelihood of fishers. Fishers at first instance are not aware of the terminology of climate change, but when it is explained to them by a change agent /extension worker at the field level that climate change is a significant and lasting change in the distribution of weather patterns over periods ranging from decades to millions of years, they are able to relate to various weather phenomena in which they have observed a change/departure from the normal course of events over the last few decades.

Vulnerability, a key concept of climate change has rendered the fisher folk to become more susceptible to the adverse effects of climate change. Fishing communities have a major role to play in the process of adaptation and mitigation of climate change effects. Against this background a study was conducted to assess the vulnerability of coastal districts of Karnataka by construction of vulnerability indices and to study the climate change effects with respect to environmental impact, fishery impact, social impact, and economic impact and development drivers' impact as was perceived by the fisher folk. The vulnerability index for each coastal district was worked out by adopting the method developed by Patnaik and Narayanan, 2005.

Data was collected using well-structured interview schedules using village survey schedules for 6 individual villages and household schedules for individual households. Data was collected from 125 households per village thus totalling to 750 households which formed the total sample for the study. Besides data collection using structured schedules, focus group discussions, freewheeling interviews and Participatory rural appraisal methods and Rapid rural appraisal techniques were used in the study villages in order to get greater access to the fisher communities. The results of the study revealed that, Udupi district has the highest vulnerability index of 0.460, followed by Dakshina Kannada with an index of 0.418 and Uttara Kannnada with the lowest index of 0.362. Out of the 41 fishing villages of Udupi district 6 fishing villages namely Thenkayermal, Mattu, Kadekar, Udyavara, Paduthonse, and Maravanthe were selected for the study based on social, economic and geographical parameters. The vulnerability indices (V.I) were worked out for the selected fishing villages. It could be inferred that, the fishing village of Maravanthe had the highest V.I of 62.05 closely followed by Thenkayermal with V.I of 61.58 and Udyavara with V.I of 61.55.

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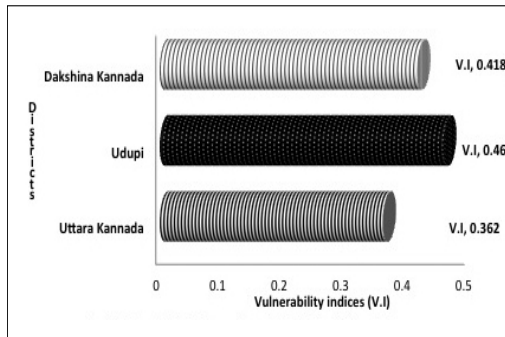
Fig 1: Vulnerability indices of coastal districts of Karnataka
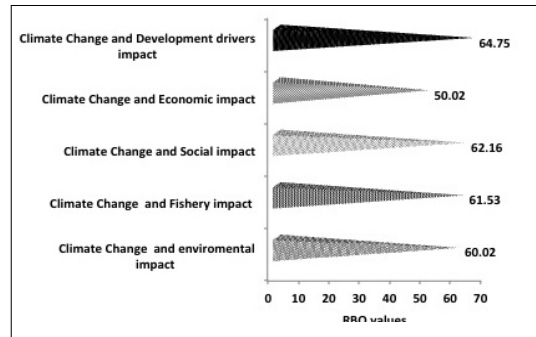
Fig 2 : Climate parameter assessment of the composite villages

The climate parameter assessment of the composite villages using Rank based Quotient (RBQ) revealed that the parameter namely climate change and development driver ranked first (RBQ of 64.75) among fisher folk followed by climate change and social impact (RBQ of 62.16), followed by climate change and fishery impact.(RBQ of 61.53). An attribute analysis for the development drivers indicated that among the development drivers such as infrastructure drivers, productivity enhancement drivers, anthropogenic drivers, ICT enabled drivers and policy support drivers, anthropogenic drivers had impacted the fisherfolk most with an RBQ value of 60.68.

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Marine litter - A problem for stake net fishers: A case study in Vembanad Lake, Kerala

Shylaja, G.*, V. Kripa , D. Prema , K. S. Abhilash, K. S. Aswathy and Gishnu Mohan
Central Marine Fisheries Research Institute, Kochi 682 018, Kerala, India.
Email: g.shylajacmfri@gmail.com

Plastics have become an inevitable item in daily life. Since they are non-degradable and persist for centauries they are considered as one of the most serious threats to the marine ecosystem in the current century. Marine litter consisting of plastics and other non-biodegradable material reach the sea through rivers and estuaries due to improper disposal or sometimes are discarded directly into the ecosystem. The coastal waters are important fishing areas where traditional fishermen use different types of craft and gear to harvest the fish from the natural waters. The progressive increase in plastics and their indiscriminate discards have affected the ecosystem and also the fishers who depend on the ecosystem.

The present study was conducted among the stake net holders to estimate the abundance of plastic litter entering to Arabian Sea through Vembanadu Lake during the heavy rainfall season and also to know how it affects the fisheries. The study was conducted at Panambukadu village of Ernakulum district (Lat10°00'35''N and

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Long76°14'547'' E) which is about 3.5 to 4 kms downstream of Vypin Ferry. The major livelihood of the people is fishing.

Stake nets are normally operated in the shallow waters and estuaries where the tidal currents are strong. They are fixed conical bag nets with rectangular mouth opening kept open against the current by means of stakes driven to the bottom. The principle of operation here is that the organisms which drift with the tidal current enter the net set against the current, and are filtered and retained in the cod end (Boopendranath and Hameed, 2010).

This conical bag net is made several cylindrical sections of the netting, diminishing in diameter progressively from the mouth to the cod end. The stakes are installed in series at a distance of 4.5 m, to facilitate the operation of a number of nets. The net is set at the onset of ebb tide. The hauling is done when the tide begins to slacken towards the end of the ebb tide. Stake nets are normally operated for catching prawns.

Many countries have started research on the marine litter and the United Nations Environment Programme (UNEP) has tried to sensitize the issue and attributed Remote Litter Codes (RLC) to categories the items which persist in the ecosystem for a long period.

Eighteen numbers of stake net holders were contacted individually and garbage bags were distributed to them. The collected litter was sorted as per UNEP guidelines, weighed and counted to estimate the abundance of the same. Out of the different categories of litter, plastic carry bags were predominant (RLC15) and recorded a maximum weight of 21.8 kg on the second day of observation, with an average weight of 1.67 Kg per stake net (Fig1). The volume of water passed through the net of dimension 12x4x6 m^3 during the operational period was 16981cubic meter of water per hour with an average flow rate of 0.21m/sec and a maximum number of 608 items were collected during a two hour operation. The maximum accumulation of plastic carry bags on individual stake was found on the fourth day of operation with an amount of 4.8 kg which was comparatively a heavy rainfall day contributing to heavy runoff and under water current resulting in dragging of more quantity of litter from the upstream and near shore areas. The other litter categories observed were plastic bottles, cups, metal caps, spoons, diapers etc.

The paper presents the quantity of plastics in each net, the average catch and a list of commonly and rarely occurring items in the stake nets.
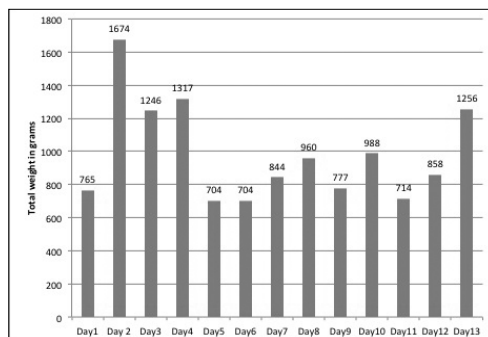
Fig.1. Average weight of plastic covers (gm /stake net/ day) in the stake nets near Panambukad of Vembanad Lake during monsoon

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Assessing the climate change knowledge of marine coastal communities in coastal Kerala

Shyam, S Salim*,T .V .Sathianandan, P. S. Swathilekshmi, R. Narayanakumar, P. U. Zacharia, Pratibha Rohit, Nivedita Shridhar, U. Manjusha, Bindu Antony, P. K. Safeena, M. Ramees Rahman, Rajani Jayakumar, Nimmy S. Kumar and C. P. Nimisha
Central Marine Fisheries Research Institute, Kochi 682 018, Kerala, India. Email: shyam.icar@gmail.com

Climate change is a major concern that is affecting the communities around the globe. Initiatives to identify adaptation and mitigation needs and thereby improve adaptive capacity increasingly start with assessing the vulnerability of the system of interest. The first step in developing a climate resilient community is to unravel the perception of the primary stakeholders, primarily the fishers. The study attempts to determine the scope of developing bottom up adaptation and mitigation plan for the community through a comprehensive yet extensive analysis of the community perception on climate change impacts, vulnerability and their knowledge on the existing adaptation mitigation strategies. The study was conducted in two fishing villages of Ernakulam district, viz., Ochanthuruth and Njarackal based on identified socio economic parameters. The research explored the impact of climate change on both resource and resource users, and the probable impacts and visible features of the climate change. Perception analysis was employed using comprehensive interview schedule administered across 300 fisher households. Analytical Techniques such as Garett ranking and correspondence analysis was applied in deriving the results.

The study opened new horizons in stakeholders' perception of climate change; the survey showed that the respondents in general have a hazy picture of the underlying causes, the expected and observed effects of climate change. The survey further showed that the community's understanding about the causes of climate change was narrow and chaotic. Majority of the respondents claimed that climate change was the result of human activities, rather than a result of natural variations. 72 percent of the respondents strongly believed that climate change is due to the aftermath of industrialization and subsequent urbanization, habitat destruction, pollution and transportation etc. In reference to visible features of climate change as seen (Fig. 1), a large proportion of respondents indicated that the local climate has been altering since their childhood. However they felt the impact over the years differ. 97 percent of the respondents were of the opinion that the temperature rise is the most affecting variable in the context of visible features of climate change, followed by changes in wind pattern (65 percent), sea water intrusion (40 percent), availability of water (35 percent), erratic weather (20 percent). The correspondence analysis (Fig. 2) employed determines the association of respondents' level of awareness on climate change with a composite index of education, experience, proneness to natural disasters and availability of multiple income sources.

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The overall picture exposed that the science of climate change as well as consequences of climate change impacts in a long run was not perceived well. The primary stakeholders found it impossible to link the uncertainty in their livelihood to climate change, and were only marginally aware about the concept of climate change. The study suggests that concerted efforts in bringing about resilient community can be achieved through incorporating the primary stakeholders in every step of the planning process, beginning from inception, awareness creation and developing the adaptation and mitigation strategies integrating modern science and technology coupled with indigenous knowledge. Such plans would facilitate in tackling global issues of climate change through local solutions which are area and issue specific.
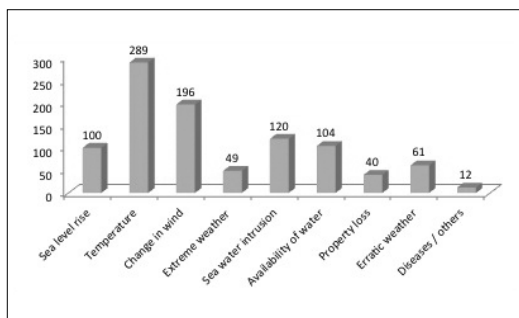
Fig. 1. Perception on the visible features consequent to climate change
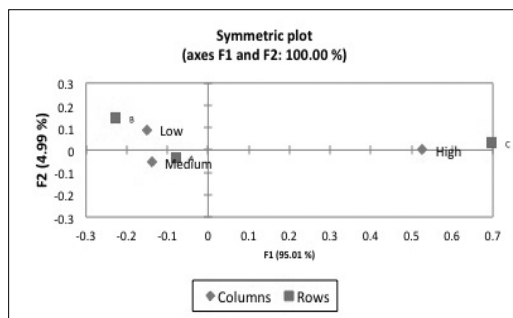
Fig. 2. Correspondence analysis for the level of awareness on significant impact of climate change on marine resources.

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Contemporary changes in biodiversity of Chilika lagoon, east coast of India

Biraja Kumar Sahu*, Premalata Pati and R. C. Panigrahy
Department of Marine Sciences, Berhampur University, Berhampur 760007, Odisha, India.
Email: birajkumar@gmail.com

Chilika (=Chilka) lake, situated along the Odisha coast on the east coast of India (latitude 19° 28'-19° 54'N and longitude 85° 05'-85° 38'E), is Asia's largest brackishwater lagoon which stands as one of the prominent biodiversity hotspot along the Indian coasts. The lake has undergone many visible changes over the years under the influence of natural processes and anthropogenic interventions. The physical changes which have affected its ecology and biodiversity are siltation and shrinkage of waterspread area, fall in salinity and shifting of bar mouth that controls the water exchange between the lagoon and the sea. The important anthropogenic influences included the gheri culture (pen culture), chemical pollution and unsustainable use of resources like overfishing, tourist boat operations etc. Studies have revealed that ecological changes of the lake system

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and its fisheries are largely influenced by the water exchange between the lake and the sea, which in turn controls the salinity, siltation, macrophyte infestations and recruitment of marine forms. Record depletion in fisheries catch, rank order distribution of different species, and overall loss of biodiversity was noticed during 1980s and 1990s which were linked to northward shifting of lake's inlet and silting up of the outer channel restricting water exchange. Based on scientific findings, a new mouth was dredged open on 23rd September 2000 in order to improve the health of the lagoon and restore its biodiversity. This exercise has facilitated better water exchange between the lake and the sea and thereby improved the overall water quality especially the salinity. Visible increase has also occurred in fish and shell fish yield and change in biodiversity. In this paper, the biodiversity scenario of pre and post hydrological intervention is described and discussed. Emphasis is also laid on the future prospects of biodiversity sustainability withstanding the predicted exogenous interventions through manmade activities, climate change impacts and coastal processes.

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Studies on the morphological features of Schyphozoan upside down jellyfish, *Cassiopea andromeda* recorded from a biofilter facility

Ranjith, L*, R. Saravanan, S. Ramkumar and P. R. Behera
Central Marine Fisheries Research Institute, Tuticorin Research Centre, South Beach Road,
Tuticorin 628 001, Tamil Nadu, India. Email: ranjith_bfsc@yahoo.co.in

The circumtropical upside-down jellyfish, *Cassiopea andromeda* are semi-sessile, planktonically dispersed scyphomedusa exhibiting a benthic life. These are found to occur in calm, shallow, tropical inshore marine waters on sandy mudflats and are usually associated with mangrove-dominated habitats. The present record was from the seawater reservoir kept for filtration at Tuticorin Research Centre of CMFRI. This species was found in the bottom of the shallow reservoir showing the ex-umbrella to the sediment and exposing the oral appendages to the surface to sunlight, as the large portions of their nutrient are coming from their intracellular symbiotic zooxanthellae. It is suggested that the species has metagenetic reproduction (sexual reproduction alternating with asexual reproduction in each generation). In addition, the entry of medusa in to reservoir was not easy; possibly the larval form should have gained entry intake pipe system and gots established, as there were no strobilation was found in the tank. The recorded specimens were photographed and their bell diameter was 60.6±8 mm. The detailed meristics and morphometric features were described and discussed in the paper. Moreover, a global phylogeography and molecular systematics of this species has to be studied in future to resolve the controversy over the taxonomy of upside-down jellyfishes precedes and persists today.

Assessment of provisional ecosystem services in Vypin Island, Cochin backwater and payment for coastal ecosystem services

Abhilash, K.S.*, P. G. Vishnu, Abbas A Muhammed, T. V. Ambrose and V. Kripa
Central Marine Fisheries Research Institute, Kochi 682 018, Kerala, India. Email: abhilashks79@gmail.com

Ecosystems are a fundamental part of human lives; the very survival of human race is dependent on the assistance provided by ecosystems. The benefits people obtain from their ecosystems, and which contribute towards their well-being, are known as ecosystem services (MA, 2003). The ecosystem services include material and non-material benefits. To define these material and non-material services, the Millennium Ecosystem Assessment (MA) working group divided ecosystem services into four distinguishing categories; provision, regulating, cultural and supporting services.

The study area for this work is Vypin island which is bound by Cochin backwater. This backwater is a part of long chain of lake and canal extending between Lat 9°40"12'E: Long.76°09"52'N and Lat.10°10"46': Long. 76°23"57'N. In Cochin backwater there are three major island namely Vypin, Vallarpadam and Bolgatty Island. Vypin island is the biggest island and is bound by the Arabian sea at western side and Cochin backwater in the eastern side. The total area of island is 56.49sq.km.

The aim of this study was to assess the links between provisional services and human well being for a rural community in Vypin Island, Cochin district. The study was carried out using socioeconomic survey of coastal village associated with Cochin backwater. The initial phase of study was to understand the services being harnessed by the population associated with Cochin backwater in Vypin Island. This led to the understanding of the demographic status and lifestyles in order to get an insight into well being. The village household studied relies mainly on fishing for their livelihood and income as part of direct use of ecosystem. A small part of population depended on shrimp farming, masonry work, labor work related to boat and net repairing. The provisioning services harnessed from the backwater were mainly fishes and crustaceans which varied seasonally. The major catch comprised of mugils, lizard fish, catfish, pearl spots, tilapia, groupers, milk fish, *Gerrus* sp, *Leognathus* sp, *Lutianus* sp, *Thryssa* sp, etc. The crustacean fishery comprised of scampi, *Metapenaeus dobsonii, M. affinis, M. monoceros, Feneropenaeus indicus, P. semisulcatus, P. monodon, P. canaliculatus, Acetes indicus, A. erythraeus, Scylla serrata* (mud crab) etc.

A total of 75 fishermen were selected for the interview and their age ranged from 18 to 74 years old with an average age of 40. About 92% of fishermen were married. Sixty percent of fishermen had basic education up to primary school

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level while 13% had secondary school level education. The male gender were fully involved with fishing activity which come under the age group of 40-50 year and have more than 20 years of fishing experience which comprises of 73% of fishermen respondents. 12% respondents of age group 20-30 and above 50 years of age are actively generating income from fishing activity. The annual income from each house of the respondent is approximately Rs. 1.5 lakhs per annum. 83% of fishermen are fully depended on fishing from backwater and rest of them was involved with masonry work, boat and net repairing work during non-fishing time. The income spends for household expenditure which included maintenance of house, education, water, electricity health needs and travelling were approximately Rs.36000 per annum. The pattern for net monthly income was slightly different, with 63% fishermen noticing a decrease compared to earlier years. Almost all the fishermen reported that while fish prices have increased in recent years, fish catch has decreased and cost of fuels, fishing gear and boat upkeep have increased, resulting in a decrease in their net income. The cause for fish catch decline ranked according to the respondent are mainly over fishing, pollution from factories, peeling shed, dumping of poultry waste, effluent from industries and disposal of plastics in the water bodies.

For the contribution on payment for coastal ecosystem services on 83% of the respondents are willing to pay for better sustainability of the water body associated with Vypin Island. They are willing to pay 1%-5% of their annual income for protection of their livelihood and environment. This work on provisional services provides critical information for awareness, advocacy and policy work for ensuring the maintenance of ecological functions for ecosystem services in order to support human wellbeing.

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Biomonitoring natural radionuclides in tuna fishes and assessment of dose

Feroz Khan, M.* and S. Godwin Wesley
PG and Research Department of Zoology, C. Abdul Hakeem College, Melvisharam 632 509, Vellore District, Tamil Nadu, India. Email: ferozmerlin@yahoo.co.in

The possible transfer of radionuclides to human beings through marine foods and the assessment of safety limit are of paramount importance in recent years. Baseline assessment of natural radionuclides near nuclear installations receives more attention as far as its pre-operational study is concerned. The assessment of radionuclide Polonium-210, a member of ^{238}U decay-series is considered crucial for its toxicological significance and its special accumulation behavior in the environment. Comparatively, ^{210}Po accumulates more in marine fishes and delivers a higher dose to humans through intake of seafood. Marine fishes are potential bioindicators when they bioaccumulate the target radionuclide from surrounding waters. Monitoring radionuclide levels in fishes assumes greater importance: (i)

due to their significant contribution to natural radiation dose received by human beings consuming them; and (ii) understanding the radiological sensitivity of the fishes. India's biggest nuclear power plant at Kudankulam is situated 30 km to the east Cape Comorin, from where sampling has been done in the present study. After Fukushima accident, baseline data is considered to be an important parameter to address radiological dose assessment around Nuclear Power plants.

Tunas are among the largest, most specialized and commercially important of all fishes. Belonging to the genus Thunnus of the family Scombridae, are found in temperature and tropical oceans around the world and account for a major proportion of the world fishery products. Tunas are in great demand throughout the world market due to their excellent meat quality. Based on the above scenario, the present study was focused on quantifying the level of ^{210}Po in certain species of tuna and assessing the associated radiological risk.

Fish samples were collected from landing centres (Chinnamuttom, Idinthakarai and Arokiapuram) along the southern tip of India. The prime fishing season extends from June to September. Pelagic and demersal fishes of this coast are consumed largely by the local population and shell fishes are mostly exported. The collected tuna samples were brought to the laboratory and washed thoroughly with tap water. The fishes were identified and their ecological characteristics and distribution were obtained from Fishbase online. Samples were oven-dried at 105°C, homogenized and analysed. Seawater (~150 l) samples were collected from the inshore (5–6 m deep) and offshore (25–33 m deep) water. Seawater was filtered with a filter with 0.45 μm pore size immediately after sampling, and the filtrate was acidified to pH 1 using HNO_3. The ^{210}Po activity of seawater and fishes were determined by electrochemical deposition.

The normal distribution of the data set was checked using Lilliefor's test (n≥50) and potential outliers, if any, were tested using Walsh's test (n>60). These tests were performed using ProUCL v 4.0. Polonium-210 concentrations in seawater ranged from 0.9 to 2.3 mBq l-1 (Fig.1). Overall, the concentration of ^{210}Po in the fish muscle tissue alone ranged from 40.9 ± 5.2 to 92.5 ± 7.9 Bq kg^{-1} (Table 1). All the activity data followed normal distribution at 95% confidence level and there were no potential outliers. Higher activity was noted in *Euthynnus affinis* and the lowest in *Auxis thazard*. The significant variability in 210Po activity concentrations was recorded in different species depending on the affinity of the considered radionuclide. Lower activity concentration of ^{210}Po in fish muscle tissue is important to humans, who consume mostly this part. On comparison with global data on the accumulation of ^{210}Po by fishes, there stands a difficulty in attributing a wide variation on the difference in feeding habits. 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}.
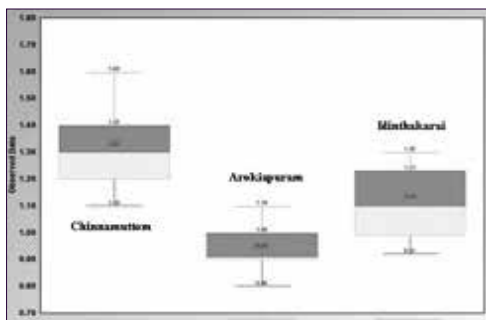
Fig. 1. Box plot showing 210Po in seawater

The [210]Po daily intake of each muscle tissue of fish varied between 2.3 and 23.7 Bq y[-1]. The estimated dose due to [210]Po intake ranged from 5.4 to 32.5 μSv y[-1]. The calculated dose values are lesser than the average natural radiation received by people worldover (2400 μSv y[-1]). Polonium-210 alone contributes to >95% of the natural radioactivity received by the Kudankulam public. Higher effective dose received may be due to higher intake of fishes, which in turn concentrate more [210]Po. The variation in accumulation in tunas may be due to the habitat and feeding habits of the fishes. Among fishes, highly predatory carnivores display more activity. The data reported in this study provide reference values for the coastal waters and other organisms of south India. The results obtained in this investigation was low compared to that in other regions, which indicates that it will not have any significant impact on human health and the environment. The study assumes greater significance in providing the baseline data for the Nuclear Power plant being operated at Kudankulam.

Table 1. 210Po concentration in tuna fishes

Scientific Name	Common Name	Habit and Habitat	210Po Concentration (Bq/kg wet)
Euthynnus affinis (Cantor, 1849)	Kawakawa	Marine; pelagic-neritic oceanodromous	92.5 ± 7.9
Thunnus albacares (Bonnaterre, 1788)	Yellowfin tuna	Marine;brackish; pelagic-oceanic; oceanodromous	72.3 ± 9.7
Thunnus tonggol (Bleeker, 1851)	Longtail tuna	Marine; pelagic-neritic; oceanodromous	48.5 ± 12.3
Katsuwonus pelamis (Linnaeus, 1758)	Skipjack tuna	Marine; pelagic-oceanic; oceanodromous	82.5 ± 10.3
Auxis rochei rochei (Risso, 1810)	Bullet tuna	Marine; brackish; pelagic-neritic; oceanodromous	56.6 ± 6.5
Auxis thazard thazard (Lacepède, 1800)	Frigate tuna	Marine; pelagic-neritic; oceanodromous	40.9 ± 5.2

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Taxonomy and molecular description of *Labidocera acuta* Dana, 1849 (Calanoid copepod) from Lakshadweep Archipelago, south west coast of India

Bijoy Nandan, S., V. F. Sanu*and M. Harikrishnan
Department of Marine Biology, Microbiology and Biochemistry, School of Marine Sciences, Cochin University of Science and Technology, Kochi 682 016. Email: sanuvf@gmail.com

Labidocera acuta Dana, 1849 belonging to the family is chiefly a neritic species, widely recorded from Indian seas (Thompson, 1900; Sewel, 1912; Menon, 1931; Krishnaswamy, 1953; Ganapathi and Rao, 1954; Kasthurirangan, 1963; Silas and Pillai, 1973).The species was originally described as *Pontella acuta* by Dana, 1849 later it was described as *Labidocera acuta* by Giesbrecht and Schmeil, 1898. Even though the taxonomic description of the species had already been reported from

the study area, the present study was based on morphological as well as molecular genetic approaches by developing mitochondrial COI sequences of 641 base pairs. The molecular techniques are now used as an important tool for studies on population structure, phylogeography, and phylogeny of copepods (Ryuji *et al.* 2002).

L. acuta was collected along with the mesozooplankton samples from Kavaratti Island (10°33'N and 72°36'E) during April 2013 (Premonsoon), September 2013 (Monsoon) January 2014 (Postmonsoon) using a plankton net (mesh size 200μm) with a mouth area of 0.28 m^2. The samples were fixed in 4% buffered formalin and in 95 % ethyl alcohol for morphological and molecular examinations respectively. Species were identified to the lowest possible taxa using standard keys (Mori, 1964; Silas and Pillai, 1973; Conway *et al.*, 2003). Genomic DNA was extracted from individual copepods using DNeasy Blood and Tissue Kit (Qiagen). The primer pair used was LCO-1490 and HCO-2198 for amplifying mtCOI gene sequences from the selected samples (Folmer *et al.* 1994). PCR Amplification was performed with 50μL samples using gradient thermal cycler (Agilent sure cycler 8800, 2012). The PCR kit used was Takara EmeraldAmp® GT PCR MasterMix. PCR products were purified and sequenced. Sequences were compiled using BioEdit 7.0.9 (Hall 1999). Alignment was performed using Clustal X (Thompson *et al.*, 1997). Phylogenetic analysis using Neighbour joining tree and Intraspecific pair wise sequence distance within the species were calculated using Kimura 2-Parameter model by MEGA 5 (Tamura *et al.*, 2011).

One-hundred and thirty-two females and seventy two males were collected from lagoons of Kavaratti Islands, Lakshadweep archipelago during the study period of which ten females and ten males of *L. acuta* were dissected and closely examined. In the study, the species was found to occur in haline range of 33 to 37 psu, pH of 7.72 to 8.76 and temperature of 27 to 30°C. The species dominance pattern varied with seasons. During premonsoon *Labidocera acuta* contributed 3.6% of the total mesozooplankton, followed during monsoon by 1% and during post monsoon by 5.5%.

Description: FEMALE: Body length 3.05-3.40mm, cephalon rounded with a conspicuous anterior rostral hook. No lateral cephalic hooks; posterior metasome symmetrical with large lateral points. dorsal eye lenses moderately large, rostrum deeply bifurcate, ; First antennae with 25 segments; urosome three-segmented, about one-third length of prosome ; genital segment asymmetrical with a stout postero-lateral conical process present on its right side which extends half way along the next segment. Anal segment well developed. Fifth leg markedly asymmetrical with a rather variable exopodite, with relatively large spines on the outer border; endopodite is claw like.

MALE: Body length 2.80.-3.30mm. Cephalon resembles that of female except that dorsal cuticular eye lenses are larger and placed close together, Right first antennae geniculate, segment 18 with prominent denticulated ridge. Urosome five segmented; Urosome segment 1 with a small spine on the right. Left fifth leg with 3 terminal and 1 outer spine; right fifth leg without a thumb on the claw, but with a curved triangular flap. (Fig.1)

COI sequences of *L.acuta* obtained were submitted to NCBI database and the

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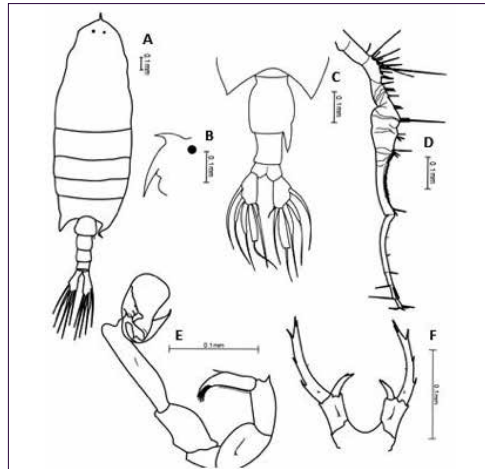
Fig. 1. *Labidocera acuta* : A, Male dorsal; B, head lateral; C, Female urosome dorsal; D, Male geniculate first antennae ; E, male fifth leg; F, Female fifth leg.

following accession numbers were obtained (KJ940167, KJ940168, KJ940169 and KJ940170). Additional sequences of genus Labidocera present in NCBI database were incorporated for constructing phylogenetic tree. An out-group selected was *Pseudocalanus elongatus* Boeck, 1865. The genetic congruence of these sequences is evident by its assemblage within the Maximum Likelihood (ML) tree as they formed a major clade with a bootstrap support of 98% (Fig.2) Further conformation regarding the authority of these sequences in establishing the speciation of *L. acuta* is revealed from the distance matrix which exhibited an intraspecific divergence ranging from 0.2 % to 0.3 % which is well accepted. It could be summarized that the mentioned data confirms the taxonomy of *L. acuta* in terms of its morphological and genetic basis.
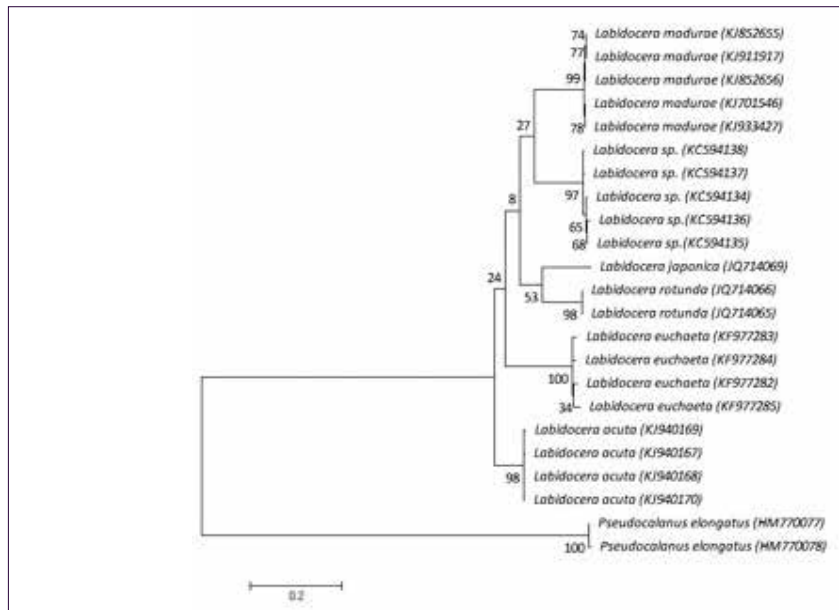
Fig. 2. Phylogenetic ML tree based on 1000 pseudo replicas of bootstrap.

Bioturbatory activities of *Lingula anatina* in an ecotone of Midnapore (East), West Bengal, India.

Samanta, S.*, A. Choudhury and S. K. Chakraborty
Department of Zoology, Vidyasagar University, Midnapore 721 102, West Bengal, India.
Email: ss.lingula@gmail.com

Bioturbation is one of the major bio-geo-physico-chjemical processes influencing ecosystem functioning. Burrow density, burrow depth, bio-volume and species-specific life modes determine the impact of bioturbation on the ecosystem. Experimental study both in the field and in the laboratory was conducted on *Lingula anatina* to record their mode of burrow formation and quantify bio-volume amount. The integrated biogenic rate of turnover of nutrient and sediment associated with interstitial water and consequent changes in geochemistry have been documented with the matrix scoring method. The present paper has attempted to evaluate the role of this faunal component in the bioturbation process of a selected mangrove-coastal-estuarine ecosystem.

Responsible Harvest and Post-harvest

Track 4

Chlorophyll based new production estimates as a baseline data for assessing potential fish harvest from Indian EEZ

Jayasankar, J., Grinson George*, K. G. Mini, Somy Kuriakose, Wilson T. Mathew and Pratibha Rohit

Central Marine Fisheries Research Institute, Kochi 682 018, Kerala, India. Email:grinsongeorge@gmail.com

Assessment of marine resource potential off Indian EEZ has been a vital task to be carried out before crucial planning interventions of the government. Apart from fin and shell fishes, the marine domain is interacting with many organisms which have direct and indirect role in deciding the potential of the EEZ. As the resource domain and its actual extent of spread is an unknown entity, predictions based on indices obtained on shore have played a major role in reassessing the marine resource potential. With the advancement of technologies like remote surveillance, marine areas are more approachable from a synoptic scale.

Ocean colour data (remotely sensed chlorophyll) is physically a reasonable estimate of algal biomass (ML^{-3}) present in a water column (L) is an essential pre-cursor contributing to fish production ($ML^{-2}T^{-1}$) which is the annual rate of production of fish biomass per unit area of sea bed. Rate of production of chlorophyll (or primary production) physically is dimensionally consistent with fish production but has lot of biological complexities. Primary production in the water column can be studied in the context of bio-available nitrogen in the ocean so as to differentiate the primary production process into regenerated production (P_r) and new production (P_n). P_r is supported by the reduced nitrogen form ammonia (NH_4^+) and represents the maintenance production required for sustaining the pelagic ocean systems. P_n is the available surplus in primary production generated from oxidised nitrogen (nitrates). Therefore, ideally the P_n or a fraction of P_n will contribute to the fish production process. Hence, for estimation of annual fish production in the EEZ we need to determine the surplus chlorophyll biomass generated annually in Indian EEZ in P_n.

The present trends, based on the estimated Chl-a production at different geographic strata of India, have shown high level of association with the trends in the pelagic fishery attributable to coastal fishery. Hence, an attempt has been made to analytically decipher the seasonal and spatial fluctuations in the associativity and their possible portends onto new poduction (P_n).

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Quality characteristics and food safety hazards associated with striped catfish Pangasianodon hypophthalmus marketed in Kerala

Laly, S. J.*, Satyen Kumar Panda, S. Sanjeev, and T.V. Sankar
Central Institute of Fisheries Technology, P.O. Matsyapuri, Kochi 682 029, Kerala, India.
Email: laly_jawahar@yahoo.co.in

Striped catfish (*Pangasianodon hypophthalmus*) is an important aquaculture species having very high demandin recent days. Large quantityof the fish is farmed in Andhra Pradesh and transported in ice boxes and sold indifferent marketsacross the country.The marketing of chemically treated fishes mainly formaldehyde and ammonia in the domestic markets of Kerala has raised health concern among fish eaters. Also commercial farming of this catfish under eutrophic condition raises the possibility of heavymetal contamination. Market samples were collected and assessed the proximate composition, biochemical indices like pH, TVBN, PV & FFA and chemical contaminants such as formalin, ammonia, pesticides and heavymetals such as cadmium, cobalt, chromium, copper, iron, manganese, nickel, lead & zinc. The catfish samples were found in good and acceptable condition in terms of biochemical indices of quality. Formaldehyde content was in the range of $0 – 0.45 \pm 0.06$ ppm in catfish samples. The low level of formaldehyde can be due natural *in situ* formation rather than chemical contamination. Ammonia was found in the range of $0 -18.48 \pm 0.42$ ppm and it can be natural due to spoilage of fish.Organochlorine pesticides were non-detectable. The heavy metals such aschromium, copper, iron, manganese, nickel& zincwere found well below the recommended limits in all the samples and among the metals cadmium, cobalt and lead were not detected. In terms of microbiological quality, the mesophilic bacterial load was found in the range of $7.05 \times 10^4 - 4.05 \times 10^6$ cfu/g. Load of *Staphylococcus aureus* was always less than <10 cfu/g, whereas *Escherichia coli* was detected as high as 3.4×10^3 cfu/g in some samples. Although *Vibrio cholerae* and Listeria monocytogenes were not detected in any of these samples, presence of highly pathogenic bacteria like *Salmonella* and *Escherichia coli* O157 in 50% of the samples indicated poor post- harvest handling practices during transport and marketing.

Technical efficiency of small scale fishing units in Kerala

Jeyanthi, P.*, Nikita Gopal, Chandrasekar, V. and S. Balasubramanium
Central Institute of Fisheries Technology, Matsyapuri, Kochi 682 029, Kerala, India.
Email: tvjeyanthi@gmail.com

Kerala contributes 20 per cent to the marine fish production in India. Marine fishery is considered to be the only source of livelihood for more than 8 lakh marine fishermen in the state. Among the fishing units in Kerala, more than 80 percent are motorized, which is categorized as small scale fishing units. Even though, small scale fisheries are literally defined as less input intensive, the situation is changing with changes in the type of fishery. This paper examines the technical efficiency of small scale fishing units in Kerala and covers two types of motorized fishing crafts namely Marine Plywood Craft and Mini-trawler in Thiruvananthapuram and Alappuzha districts respectively. The technical efficiency was assessed using Cobb-Douglas Production Function and Stochastic Frontier Production model.

Combined effect of O_2 scavenger and essential oil on the quality of packaged fish

Remya, S.*, C. O. Mohan, J. Bindu, G. K. Sivaraman and C. N. Ravishankar
Central Institute of Fisheries Technology, Veraval Research Centre, Veraval 362 269, Gujarat, India.
Email: remya03cof@gmail.com

Active packaging systems, which provide better quality, wholesome and safe foods, have started to receive a great deal of attention since the last decade. In the present study, effect of a novel active packaging technology using O_2 scavenger on the quality and shelf life of cobia (*Rachycentron canadum*) fish steaks pre-treated with curry leaf (*Murraya koenigii*) essential oil during chilled storage was evaluated. The fish steaks of 2 cm thickness were divided into four batches, i.e., AP, EO, OS and EOOS. The first batch (EOOS) of fish steaks was dipped in 1% (v/v) curry leaf essential oil for 15 minutes in chilled condition prior to packing with an O_2 scavenger (Ageless® ZPT 200 EC O_2 absorber). The fish steaks of second batch (EO) were treated with curry leaf essential oil and third batch (OS) of fish steaks was packed with O_2 scavenger. The fourth batch (AP) of aerobically packed fish steaks was kept as control. Further, all the packs were sealed using a heat sealing machine and stored at 2°C. During storage, samples in triplicate were drawn regularly (0, 6, 12, 18, 24, 30, 36 days) from each batch for bio-chemical, microbiological and sensory quality analysis. Moisture, crude protein, fat and

ash contents of fresh cobia were determined as 68.64±0.02 %, 16.45± 0.15 %, 11.65± 0.5 % and 1.12±0.02 %, respectively. Initial value of pH was 5.55 and the value of total volatile basic nitrogen (TVB-N) was 8.6 mg N_2 per 100 g flesh. Over the period of storage, there was a rapid increase in the pH and TVB-N content of air packed fish steaks compared to fishes packed with O_2 scavenger. There was a significant difference (p<0.05) in the total mesophilic count and thiobarbituricacid (TBA) value of EOOS and AP fish steaks. The total mesophilic bacterial count of AP samples exceeded the upper acceptability limit of 7 log cfu/g, after 18 days of chilled storage. Oxygen scavenger along with curry leaf essential oil treatment was effective in reducing undesirable changes in the bio-chemical and microbiological quality of cobia fish steaks, which resulted in an extended shelf life of at least 36 days while the control air pack was sensorily rejected on the day of 18. Essential oil treated fish steaks and fish steaks packed with O_2 scavenger were sensorily acceptable till 24 and 30 days of storage, respectively.

Quality of longtail tuna (*Thunnus tonggol*) chunks packed under reduced oxygen atmosphere in chilled storage condition

Mohan, C. O.*, C. N. Ravishankar and T. K. Srinivasa Gopal
Central Institute of Fisheries Technology, Matsyapuri, Kochi 682 029, Kerala, India.
Email: comohan@gmail.com

Tunas form one of the most sought after seafood commodity due to their unique taste. The fishes maintained in their freshest form fetches great price in the markets. Freshness of fish deteriorates as soon as fish is caught. Various technologies are employed to retain the freshness in which active packaging is gaining much importance in recent years. In the present work, quality and shelf life of longtail tuna chunks packed under reduced oxygen atmosphere was monitored in chilled storage conditions. The oxygen content in the pack with O_2 scavenger sachet reduced to less than 0.1% within 24 h and maintained this level throughout the storage period. Reduced oxygen atmosphere resulted in reduced rate of oxidation (Peroxide value and TBA value) in tuna chunks packed with O_2 scavenger compared to control air packs. The peroxide value increased from an initial value of 1.17 millieq kg^{-1} to 8.8 m eq kg^{-1} in control samples on 7th day compared to 7.2 millieq kg^{-1} for samples packed with O_2 scavenger on 11th day. TBA value followed similar trend as PV value and increased from an initial value of 0.15 mg malonaldehyde kg^{-1} to 2.18 and 1.74 mg malonaldehyde kg^{-1} for control and O_2 scavenger packs. Formation of conjugated dienes were inhibited significantly (P<0.05) in the samples packed with O_2 scavenger compared to control air packed samples. The histamine formation rate was significantly (P<0.05) lower for O_2 scavenger packed samples compared to control air packed samples. Total mesophilic counts exceeded 7 log cfu g^{-1} on 7th and 11th day for samples packed

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in air and O_2 scavenger packs, respectively from an initial 4.85 log cfu g^{-1}. Towards the end of storage period, total anaerobic bacterial counts were slightly more for samples packed with O_2 scavenger. Air packed longtail tuna chunks maintained eating quality up to ~5-6 days compared to ~9-10 days for O_2 scavenger packed samples indicating an extension of ~4-5 days.

Square mesh window bycatch reduction devise (SMW-BRD) for stationary bag nets of hooghly riverine system

Prajith, K. K.*, V. R. Madhu, M. P. Remesan and P. Pravin
Central Institute of Fisheries Technology, Matsaypuri, Kochi 682 029, Kerala, India.
Email: prajithkk@gmail.com

Hooghly riverine system in West Bengal is an important water body in the country with regard to its size and as an important nursery ground for the most valuable finfish, *Tenualosa ilisha*. The system provide livelihood for large number of people along the lower and middle stretch. Variety of fishing nets like gill nets, bag net, drag nets, dip nets, traps, etc. are employed to capture the fishery resources all along the stretch with maximum intensity in the lower stretch. Juveniles and sub-adults of fish and shellfish constitute major share in the catches of most of these gears, especially in the stationary bag nets. Thousands of stationary bag nets are operated in the freshwater and brackish water zones of Hooghly. Bag nets are long funnel shaped net made of polyethylene twines with very small mesh size (10 mm or less) in the cod end. In some places material used for making mosquito net is used for fabrication the cod end which can capture the smallest fry or larvae. More than 90% of the bag net catch is invariably constituted by juveniles of almost all finfish and shellfish species in the system. Destruction of juveniles is maximum during the winter migratory bag net fishery in the lower zones, when number of bag netters from other place aggregate near the river mouth and operate the nets till the end of the season.

Participatory experimental fishing trials were conducted with the help of bag net fishermen of Hoogly. Three bagnet fishing centers of Hooghly reverie system was selected representing freshwater, barckishwater and marine stretch of the river .Viz. Tribeni, Ghodhakali and Fraserganj. A square Mesh Window By catch Reduction Devise (SMW-BRD) is installed in the upper part of the bag net, which facilitate the escapement of actively swimming juveniles like hilsa.The catches were normalized based on the hours of operation and used for the analysis. Diversity analysis of catches from the different stations is as follows.

Table 1. Species diversity indices of bagnet catch from different stations

Index	Fraserganj	Ghodhakali	Tribeni
Total species	12	13	11
Margalef diversity	1.45	1.75	1.54
Pielou's evenness	0.64	0.68	0.72
Shannon index	1.61	1.73	1.71
Simpson index	0.63	0.73	0.73

ANOSIM test of the results showed that the assemblages captured in the bag nets from the Fraserganj was significantly different (P<0.01) from species captured from Ghodhakali and Tribeni centres. The species assemblages from Ghodhakali and Tribeni were not significantly different. Cluster analysis substantiated the depictions of the MDS and the ANOSIM test and is shown in figure below. The assemblages from Fraserganj showing a separate cluster at 20% similarity.

SIMPER analysis using the data showed the average dissimilarity between the Fraserganj and Tribeni centres (87.46%) and the main species contributing to the dissimilarity were crabs and *Odontamblyopus rubicundus*. Fraserganj and Godhakali centres showed the highest dissimilarity percentage of 88.36 and the main species responsible were *Tenualosa ilisha* and *Macrobrachium mirabile*. *M. mirabile* and *Tenualosa ilisha* were the major species that differentiated between Tribeni and Godhakali stations. The highest abundance of juveniles of *T. ilisha* was observed at Tribeni centre.
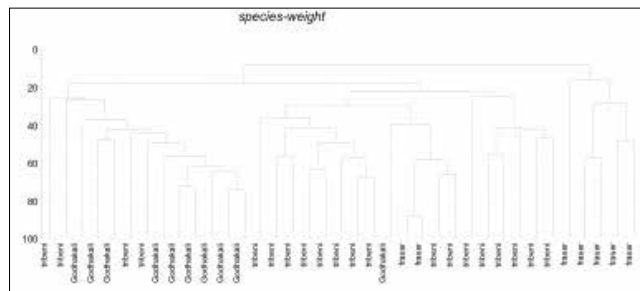
Fig 1. Cluster analysis dendrogram depicting similarity of catch composition from each bag net operation.
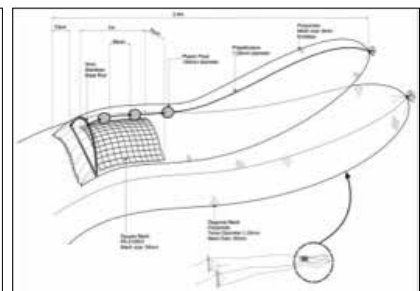
Fig. 2 Diagrammatic representation of SMW-BRD installed traditional bagnet codend

Production of high value added products using fish processing waste (FPW) as substrate

Hepziba Suganthi, S.* and K. Ramani
Department of Biotechnology, School of Bioengineering, SRM University, Chennai, Tamil Nadu, India.
Email: hepzibasuganthi.s@ktr.srmuniv.ac.in

The Fish processing waste (FPW) is generated in considerable quantity each year as a solid/liquid waste during the precooking processes of fish canning. They are rich in lipids and proteins and are usually disposed of by land filling and incineration or dumped at sea. The lipid prevents the oxygen diffusion into water and kills aquatic life. When the FPW are exposed to sewer system, they form aggregates and clogs drainpipes and sewer lines, producing an odour nuisance and sewage back-ups into residential and commercial facilities. They increases the BOD, COD, Total dissolved solids of the waste water, thus creating serious environmental havoc. The under utilization of the FPW can also increases the disposal cost. So there is a need to explore for the reutilization of the FPW so that the amount of waste disposed of and the disposal cost could be minimized.

Sustainable technologies promote the development of green techniques and products to create a clean and healthy environment. The study provides an effective and affordable synthetic process for the production of high value-added products such as enzymes (protease and lipase) and secondary metabolite such as lipoprotein/lipopeptidebiosurfactant since the FPW contain protein and lipid moieties which are responsible for the production of the above said industrially important microbial biomolecules. FPW can be used as a substitute for expensive nutrient source for the cultivation of microorganism, at the same time, recycling would reduce the quantity of biodegradable waste disposed in landfills. The enzymes (protease and lipase) are potential biocatalyst for the degradation of complex organic molecules like protein and lipid and the biosurfactants are having multiple applications such as emulsification, biosorption, heavy metal removal, etc.

To date, there is no report on the use of FPW for the synthesis of biosurfactant. In the present study, the FPW is utilized to synthesize the high value added products thereby the efforts to dispose of the waste could be greatly minimized and hence reducing the pollution in our environment.

Status survey of sea cucumbers in Palk Bay and Gulf of Mannar Biosphere Reserve, southern India

Venkataraman, K., C. Venkatraman*, Rajkumar Rajan, P. Padmanaban, K. Paramasivam and S. Shreenivaasu
Marine Biology Regional Centre, Zoological Survey of India, 130, Santhome High Road, Chennai 600 028. Tamil Nadu, India. Email: cvramanmbs@yahoo.com

Seacucumber fishery is an important source of income for the fishing communities in South Asia. In India, it has been an export commodity generating considerable foreign exchange. However, similar to reports from other parts of the World, depletion in stock sizes due tounlimited harvesting has been reported in India from Andaman & Nicobar Islands, Gulf of Mannar and Palk Bay, which was also noted by the decline in quantity of annual export. Governments'responses to this ranged from size restrictions on harvest to complete closure of this industry.Size restriction on harvest was enforced in India in 1992. With no avail on the recovery ofpopulation sizes, however, and to conserve the resources, all species of seacucumber wereplaced under schedule I category of Wildlife Protection Act, 1972 in 2001, thereby bringing in a complete ban on thisfishery. These animals have also been recommended for inclusion under Appendix-II listing of Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) to conserve their declining population. There is a heavy dependency for this fishery in Gulf of Mannar and Palk Bay bythe industry of which also contributed to the bulk of export.

The present study was conducted during January 2011 to December 2012 to assess the density and diversity of Sea cucumbers. The study involved swept area method (trawl surveys), and visual transect surveys involving SCUBA and skin diving, to cover all sea cucumber habitats and common fishing sites in Gulf of Mannar and Palk Bay (from 9° 36' 29.7"N; 78° 00' 11.0" E in Palk Bay to 08° 46' 56.8" N; 78° 16' 10.9" E in Gulf of Mannar). A total of nine species of Sea cucumbers (9 and 7 respectively from Gulf of Mannar and Palk Bay) were recorded in the present study, where *Holothuria scabra* is the only species of highly commercial value and other two species namely, *Holothuria spinifera* and *Stichopus herrmanni* are of medium value and the remaining being low valued and not being exploited. The densities of sea-cucumber species exhibited clear-cut spatial distribution patterns of species reported with densities >100 n/ha, such as *H. scabra*, *Stichopus herrmanni*, and *H. atra*. The occurrence of high densities of seacucumber species coincides with the occurrence of breeders in the case of *H. scabra* (48.2 ± 37.6 n/ha), for Palk Bay, in the season April-June, where the matured ones in smaller densities (2.5 ± 2.6 n/ha) were found in the latter part of this season (May-June). The drastic decline in densities of the matured population could be due to the intensive fishing which begins in April in this region. This paper also discusses the possible measures to conserve them.

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Impact of body size on bio-accumulation and depuration of microbial loads in the short-neck clam *Paphia malabarica*

**Chinnadurai, S.*, J. Sharma, P. S. Alloycious, K. K. Sajikumar,
V. Venkatesan, V. Kripa and K. S. Mohamed**

Central Marine Fisheries Research Institute, Kochi 682 018, Kerala, India. Email: chinnaduraitvl@gmail.com

Ashtamudi Lake is the second largest brackishwater lake in Kerala, which supports a short-neck clam fishery of around 12000 tonnes/year and the produce is mostly exported. The short neck clam *Paphia malabarica* is one of the most sought after species among clams. Because of its attractive yellow foot and delicious taste, it is exported to niche markets like Japan and other southeast Asian countries since 1990s. Very recently, this clam fishery has been certified by Marine Stewardship Council (MSC) and therefore is now open to Western markets. Food quality and safety is the most important issue in bivalve shellfish trade. The nature of the end product and the associated risks are highly significant, especially where they cross national borders and it should be warranted free from any hazards. Based on this background information, we selected clam *Paphia malabarica* as candidate species, for studying the natural accumulation of bacterial loads and depuration dynamics of coliform bacteria and evaluated under experimental conditions.

Two independent trials were assayed in a static experimental depuration system with a total volume of approximately 200 litres, with two different body sizes (Small 20^{-3}0 mm APM, Big->30 mm APM) and loading densities 1 kg/4 litres (low), 2 kg/4 litres (high). The objective was to compare the bio-accumulation of bacterial loads in two different body sizes and kinetics of the coliforms under the experimental conditions over 24h of depuration at two different densities. The pattern of bio-accumulation and depuration was similar in both the size group, the values being higher for the bigger size group. The clam kept for depuration with low density (1kg/4 litres) took only 6h of depuration to reduce the *E. coli* levels to below the threshold level as per EU standards. But high density (2kg/4 litres) depuration took 24h. ANOVA showed the bio-accumulation and depuration of bacterial loads was not significantly varied (p > 0.01) between smaller and bigger size groups. On the other hand, the depuration of total coliforms, faecal coliforms, *E. coli* and total plate count were highly significant (p< 0.01) with different time interval and varying densities.

The effects of traditional depuration, heat shucking and pressure steaming on the bacterial loads were also evaluated. The traditional depuration is a common practice in Ashtamudi Lake done by all clam fishers. After harvesting the clams, they are kept for depuration with limited water for10-12 h duration of (evening to early morning). In the morning the clams are heated for 15-20 minutes in large container covered with cotton cloth or gunny bags to maintain the heat and steam. Because the clams are over cooked, it was easy to shuck the meat

from the shells. Out of three independent traditional depuration experiments, only on one occasion the bacterial loads were reduced to below the limits. But after heat shucking, bacterial loads were reduced to well below the legal limits at all occasion. The pressure steaming also effectively brings down the bacterial loads to below the threshold levels. Hence, we recommend 6h depuration of clam with a loading density of 1 kg/4 litres and also 5 minutes of pressure steaming for superior texture and attractive colour.

Application of high pressure for the development of fish ham and shelf lifeevaluation during chilled storage

Sarika Kunnath*, Satyen Kumar Panda, J. Bindu, G. Venkateshwarlu
Central Institute of Fisheries Education, Versova, Andheri (W), Mumbai.
Email: sarikachandrasekharan@gmail.com

High pressure processing is gaining popularity as a mild non-thermal preservation techniqueWorldwide, since it has advantages over thermal approaches for processed foods with nutritional and sensory characteristics which are thermo sensitive. In the present study, fishham, a popular fishpaste product, was prepared from washed mince of croaker (*Johniussp.*) ground with other ingredients like salt, sugar, polyphosphate, corn starch, guar gum and hydrogenated fat and mixed with blanched prawn pieces. This mixture was stuffed into a polyamide casing of 9 cm dia, sealed at both the ends and vacuum packed in a plastic pouch of EVOH (Ethylene Vinyl Alcohol) copolymer.

Further, the fish ham samples were divided into four lots and three lots were subjected to different high pressures (400 MPa, 500 MPa and 600 MPa, at a constant temperature of 30°C and a dwell time of 15 minutes with a ramp rate of 600 MPa/min) while the fourth (control) lot subjected to conventional heat processing at 90°C for 105 min. All the four lots of samples, after slicing into thin pieces of 3 mm thickness, were repacked in polyester-polythene pouches and stored under chilled condition. The biochemical and microbial quality of the fish ham samples during storage were monitored at regular intervals. The pH values of fish ham samples slightly decreased during storage. Initially, the TMA (trimethylamine) and TVB-N (total volatile basic nitrogen) values showed lower values in heat processed control sample than pressure treated samples. During storage, the TVB-N value increased in all the four samples and the liberation of volatile bases were lowest in sample processed at high pressure of 600 MPa.

Changes in lipid fraction were observed by estimating the peroxide value and the amount of FFA released. The PV and FFA values were slightly higher in high pressure processed samples than control due to increased protein denaturation and exposure of reactive species. The colour values (L*, a* and b*) indicated that high pressure processed fish ham samples werelighter (L*) than pressure

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treated samples. The +a* (redness) value increased during storage,whereas +b* (yellowness) value did not show any significant difference (P<0.05) during chilled storage. Microbial quality of fish ham samples revealed that application of high pressure inhibited bacterial growth. High pressure processing at 600 MPa extended the storage life of fish ham for 8 days, compared to the control during chilled storage.

Bacterial progression in *Lethrinus lentjan* (Lacepede, 1802) from different tactical locations

Femeena Hassan*, Treesa Gracious, V. Geethalakshmi and S. Sanjeev
Central Institute of Fisheries Technology, Kochi 682 029, Kerala, India. Email: femeenahassan@gmail.com

Food safety and microbiological quality has gained great attention among the present day consumers, particularly in high moisture foods like seafoods. Absence of quality standards for the retail trade of fish and fish products is diminishing the quality of fish meant for internal trade. *Lethrinus lentjan* (white snapper) was collected from three different strategical locations, *viz*; harbour, retail shop and market on the same day. Mesophiles, Psychrophiles, Faecal *Streptococci*, *Pseudomonas, Enterobacteriaceae*, *Escherichia coli*, *Staphylococcus aureus*, Hydrogen sulphide producers, Histamine forming bacteria and *Brochothrix thermosphacta* were analysed quantitatively while qualitative analysis was performed for Salmonella, *Vibrio cholerae*, *Vibrio parahaemolyticus* and *Listeria monocytogenes*. Market samples exhibited 12.61% more mesophilic count than that of harbour samples and 9.5% more than retail samples. The increasing trend in bacterial counts was noticed in Psychrophiles, Enterobacteriaceae, Faecal streptococci, Hydrogen sulphide producers, *Brochothrix thermosphacta* and Histamine producing bacteria. Pseudomonas count of harbour sample was found to be 14.5% lower than that of retail and market samples. Pathogens like Salmonella, *Vibrio cholerae*, *Vibrio parahaemolyticus*, *Listeria monocytogenes* and *Staphylococcus aureus* were found to be absent in the analysed samples. Highest counts were noticed in the market samples and the least in harbour samples, indicating a progressive contamination from harbor to market.

Standardisation of preservative treatment of coconut wood as an alternative boat building material

James, J. P. *, K. A. Roshan, K. Shiran, V. R. Madhu, M. V. Baiju and Leela Edwin
Central Institute of Fisheries Technology, Matsyapuri, Kochi 682 029, Kerala, India.
Email: pulikottiljames15@gmail.com

The utilisation of the low value timber for different marine applications gained great importance in the context of the scarcity of *Artocarpus hirsutus* (aini) and *Calophyllum inophyllum* (punna). Coconut palm (*Cocos nucifera*) is a plantation crop widely cultivated in India, Srilanka, Philippines, Malaysia and Republic of Vietnam. Coconut wood is knotless, hard and durable.The high density of the durable portion of the coconut wood ($>700kg/m^2$) reduces penetration of preservatives into wood under normal preservative treatment methods. The main objective of the study was to standardise the preservative treatment of coconut wood with Copper- Chrome - Boron (CCB) for getting prescribed preservative retention for marine applications as per the Bureau of Indian Standards (BIS). CCB is an eco-friendly wood preservative compared to Chromated Copper Arsenate (CCA) which was formerly used for wood preservation widely. Well-seasoned wood panels of two different sizes ($3\times3\times12$ and $3\times3\times50$ cm) were used for standardisation. CCB of concentrations ranging from 6 to 8 % (w/v) in a vacuum pressure impregnation chamber, at a constant pressure ($13kg/cm^2$) was used for the study.The pressure cycles were repeated to get a maximum retention. The results showed that the panels treated with CCB of concentration 8%(w/v) attained the retention of $32kg/m^3$after eight pressure cycles. This retention limit complies with BIS standards for marine applications and the methodology can improve the durability of a low value timber like coconut wood for use in boat building.

An economical analysis of dry fish export units in Gujarat

Chandrasekar,.V.*, P. Jeyanthi and Nikita Gopal
Central Institute of Fisheries Technology, Matsyapuri, Kochi 682 029, Kerala, India.
Email: vcsecon@gmail.com

Gujarat is a major exporter of dry fish. Major species of dry fish exported from Gujarat were Catfish, Leather jacket, Bombay duck and shrimp from the places like Veraval, Okha, Una-Diu and Navabandar region. The Bombay duck landings of about 70,000 mt per annum is almost completely utilised for the dry fish

production. Ribbon fish of about 60,000 mt, shrimp about 33,000 mt and cat fish about 30,000 mt also are used for dry fish production. About 5,000 mt of dry fish per season is exported to Sri Lanka which accounts for around 90% of total exports and 10% exported to Mauritius. Eleven export unit and 350 domestic dry fish units are operating from various coastal regions of Gujarat.

In this study the data were collected from eleven export units on raw material cost, drying cost, labour wage, packing cost, transportation cost, marketing cost and margin involved and finally annualnet profit, benefit cost ratio and return on investment were worked out in the traditional methods of dry fish export unit. The drying season is from September to May. The quantity of dry fish export from each unit varies from 30 to 75 mt per month and its prices vary from Rs 80 to 220 per kg.

MECOS 2 |HPHP 06

Effect of potassium sorbate and vacuum packaging on the shelf life extension of monosex tilapia during ice storage

Parvathy, U.*, S. Mohammed Raushan, George Ninan, K. V. Lalitha and A. A. Zynudheen
Central Institute of Fisheries Technology, Matsyapuri, Cochin 682 029, Kerala, India.
Email: p.pillai2012@gmail.com

Monosex tilapia, which has comparatively better growth than common tilapia, can be obtained by utilizing techniques such as hybridization and hormone application. A study was conducted with the objective to determine the effect of vacuum packaging alone and in combination with potassium sorbate, as a chemical preservative, on the shelf-life extension of monosex tilapia stored under iced condition by evaluating certain chemical, physical, microbiological and sensory parameters. For this, samples were steaked and divided into four lots. The first lot was kept as control (Air packed Without Dip:AWOD), second lot was given dip in 2% (w/v) potassium sorbate solution for 30 minutes and air packed (AWD), third lot was vacuum packed without dip treatment (VWOD) and fourth lot was given dip in 2% (w/v) potassium sorbate for 30 minutes prior to vacuum packing (VWD). The proximate composition study indicated a moisture content of 75.69 $\pm$ 0.01 %, 17.47 $\pm$ 0.31% protein, 5.17 $\pm$ 0.04% fat and 0.99 $\pm$ 0.01% ash content respectively. The moisture content remained more or less constant with a slightly increasing trend throughout the storage period in all the samples. pH value of the tilapia samples were found to increase gradually throughout the storage period and the increase was more prominent in lots without dip treatment compared to those that were given dip in 2% (w/v) potassium sorbate. TPC studies indicated that air packed samples were acceptable upto 16th day whereas VWOD was acceptable upto 19th day and VWD remained within the acceptable limit throughout the sampling period. TMA-N showed an increasing trend and the increase was less in VWD compared to the other three lots. TVB-N increase was also observed in all the sample lots, more prominent in VWOD compared to other lots.

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TBA value increased steadily in air packed samples compared to vacuum packed samples. Variations in peroxide value of all sample lots were very low indicating a low level of fat oxidation. Free Fatty Acid was found to have an increasing trend in all the samples throughout the storage period. WHC of the samples decreased during the storage period and it could be observed that air packed samples had better WHC than vacuum packed and potassium sorbate dip treated samples had better WHC than untreated ones. Vacuum packed samples as well as potassium sorbate treated samples showed better sensory score than control.

Based on the sensory and microbiological tests it could be observed that under iced condition, monosex tilapia that was air packed as well as 2 % (w/v) potassium sorbate dip treated and air packed had a shelf life of 16 days whereas for vacuum packed samples it could be extended to three more days and for 2 % (w/v) potassium sorbate dip treated and vacuum packed samples it could be extended upto seven more days. Hence from the present study it could be concluded that application of combination preservation techniques viz., vacuum packing, potassium sorbate dip treatment and ice storage could help in extending the shelf life of monosex tilapia steaks.

MECOS 2 |HPHP 07

Large mesh Tuna gillnets operated along Odisha coast

Muhammed Sherief, P. S,* Saly N. Thomas and Leela Edwin
Central Institute of Fisheries Technology, Matsyapuri, Kochi 682 029, Kerala, India.
Email: sheriefmuhammed@gmail.com

Fishing for tuna and tuna like fishes is carried out by operating drift gill nets, troll line, hook and line, pole and line and purse seining in coastal waters. Gillnet fishing is one of the popular fishing methods practised in the marine fisheries sector of India to harvest large pelagic species like tuna.There are differences in design, rigging and operational methods of gillnets in east and west coast of India. Polyamide (PA) mono/multifilament and high density polyethylene (HDPE) are mainly used for fabrication of gillnets in Odisha. In large pelagic fisheries sector gillnet of different mesh sizes in a single fleet are very common.These nets are operated from the mechanised gillnetter operated along the Odisha coast.This paper deals with design and general features of large mesh marine drift gillnets operated for tuna, seerfish etc in Balasore, Odisha.

Trawl systems of India

Sayana, K. A.*, P. H. Dhiju Das, P. S. Muhammed Sherief, Rithin Joseph, Saly N. Thomas, P. Pravin, M. P. Remesan, V. R. Madhu and Leela Edwin
Central Institute of Fisheries Technology, Matsyapuri, Kochi 682 029, Kerala, India.
Email: sayanaanandan@gmail.com

Trawls being the most energy intensive fishing system is one of the most common fishing systems in India. The study was conducted during 2012-13 to find out the details of trawl systems operated along the coast of India. Design details of the nets were collected using structured and pre-tested questionnaire. Wooden and steel trawlers with LOA from 8 to 28 m are found operating.

  According to the depth of operation, there are pelagic/mid-water trawls, semi pelagic trawls and bottom trawls. Based on the target species, there are shrimp trawls, fish trawls, cephalopod trawls and gastropod trawls. The catch of trawlers in Indian coast comprises of shrimp, ribbonfish, croakers, threadfins, horse mackerel, polynemids, catfish, barracuda, lizardfish, flatfish, carangid, rays, crab, sardine, mackerel, pomfret, squid, cuttlefish, octopus, gastropod, etc. High Density Polyethylene (HDPE) is used for fabrication of trawl nets. The diameter of HDPE twisted monofilament used varies from 0.25 to 4 mm. Mesh size up to 8000 mm have been observed in the wing portion. Shooting, towing and hauling of the net is carried out mechanically using winches. Fishing accessories used in trawling are a pair of otter boards (trawl doors), sweeps, bridles, etc. Spherical shaped HDPE and Acrylonitrile Butadiene Styrene (ABS) floats are more commonly used whereas, Iron and lead are the common materials used as sinkers.

Soft computing techniques: An application to short term forecast of marine product export of India

Vinod K. Yadav*, Vidya S. Bharti, M. Krishnan and N. R. Kumar
Central Institute of Fisheries Education (CIFE), Mumbai 400 061, Maharashtra, India.
Email: vinod_iasri@yahoo.co.in

Time series models have been utilized to make accurate predictions in various domains. Various forecasting methods have been developed on the basis of fuzzy time series data, but accuracy has been matter of concern in these forecasts. The historical data of marine product export (in quantity) of India have been taken to implement the model. The study uses the fuzzy sets theory of Zadeh (1965) and fuzzy time series models based on order and time-invariant method introduced by Song and Chissom (1993), Chen (1996), Konstantin & Degtiarev (2005). This

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study also uses an improved and versatile method for fuzzy time series forecasting using a difference parameter as fuzzy relation for forecasting introduced by Singh (2007) and first order and time- variant methods given by Chen and Hsu (2004). The forecast to marine product export (in quantity) have also been obtained by developing an Artificial Neural Network (ANN) model using Back propagation algorithm. The study is aimed to find the marine product export forecast for a lead year by using different fuzzy time series models and back propagation algorithm for the forecast. The forecasted marine product export obtained through these techniques, have been compared and their performance has been examined. Present study infers that performance of ANN model is similar or less performer as compared to fuzzy time series methods when the dependence is linear. In such cases, use of ANN only lead to increase in complexity without significant improvement in the performance.

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Local self governance by diving fishers for green mussel of Malabar region, Kerala

Asokan, P. K.*, K. S. Mohamed, M. P. Sivadas, V. G. Surendranathan and Geetha Sasikumar
Central Marine Fisheries Research Institute, Calicut Research Centre, West Hill, Calicut 673 005, Kerala, India. Email: asokanpk@gmail.com

The green mussel (*Perna viridis*) fishery of Malabar area has of late seen a shift in the resource management strategy. The shift started first at Elathur mussel landing centre which is one of the most important landing centres. The increase in the unit price of the mussel was one of the important reasons for this change in attitude. The fishers also felt that the reason for the lean period was the harvest of mussel seeds for mussel farming in the backwaters. So there was a conflict of interest here. A resolution was taken by the fishers to stop seed harvesting. Any seed accidentally brought was to be thrown back to the sea. This led the mussel farmers to find alternate source for their requirement of seed. They had to depend on areas where no fishery exists but seeds were available in areas of south Kerala (Quilon district) and Karnataka.

About 476 boats, canoes and catamarans are involved in the mussel fishery of Malabar area and they land about 10,000 tonnes of green mussel per annum. The mussel beds are either laterite or granite formations. The granite areas are easier for picking the mussels during diving as there are few crevasses. The crafts used are either canoes, boats or catamarans. The canoes with sail are used usually by 1-2 persons, the boats have 3-18 persons and the catamarans are operated by single person.

The first change came at Elathur during August 2012. The mussel pickers formed a union with 315 members and 5-6 members were selected from each area. The areas were 1)Harbour area 2) Elathur thodu 3) Aayyapan thaya area and

4) Panni bazaar area. Totally there are 29 members in the coordination committee. Subsequently most of the mussel landing centers in Malabar area had their own committees similar to the one followed at Elathur.

The rationale for fixing the quota by the mussel pickers was that in order to get work for more number of days in a year, quota fixation is essential. The pickers believe that the mussel seeds harvested by the mussel farmers reduce their stock for harvest and do not allow any removal of the seeds. The quota varies from different landing centres as the number of pickers and also the quantity available also varies. The quota is fixed based on the recommendations of committee which they arrive at by discussion with the mussel pickers' rough assessment of the stock available. At Thikkodi and Chombala, the quota is 25 kg per person. The quota fixed for Elathur, Chaliyam and Mahe is 30 kg per person. The quota is the highest at 60 Kg per person in the landing centres of Thalasseri and Koduvalli. At Kadalazhi and Kollam, there are no fixed quota.

The implementation of regulations varies from landing centres. At Elathur, violation is seriously viewed and action is taken by auctioning the excess mussel picked. So far, the committee has just over a lakh rupees income from the auctioning of excess catch. In all the centres, the excess catch is taken by the committee in the landing centres and auctioned. Among the centres, Elathur and Thikkodi were the centres where the implementation of regulations were followed very strictly. The other centres varied in compliance. At Thalai, Thalasseri, Koduvalli and Moodadi, up to 5% variation in the quota was tolerated. At Chaliyan, Mahe and Chombala, the quota was more lax and 10 to 25% variations were tolerated.

Due to the quota system introduced during 2012, last year, the cost of mussels has gone up considerably. Even though the CPUE have come down, the increase in cost of mussel has offset this disadvantage.

Marine Biotechnology

Track 5

Transcriptome analysis reveals immune genes associated with white spot syndrome virus infection in the black tiger shrimp *Penaeus monodon*

Shekhar, M. S.*, A. Gomathi and G. Gopikrishna
Central Institute of Brackishwater Aquaculture, 75, Santhome High Road, Chennai 600 028, India.
Email: msshekhar@ciba.res.in

White spot syndrome virus (WSSV) which infects all cultivated species of shrimp results in severe economic loss to the aquaculture industry. The outbreak of this viral disease was first observed in early 1990s and still continues to be a major threat that affects the shrimp farms world over. The lack of effective antiviral therapeutics and the virulent nature of WSSV still pose challenge to control and cure the disease completely. Several shrimp genes with unknown function remain to be characterized to understand the shrimp innate immune system against WSSV infection. With recent advances made in next-generation sequencing technologies, transcriptome sequencing is being applied as a high-throughput tool for gene expression profiling. As an approach to investigate the host–pathogen interactions which might help to understand viral infectivity and defence mechanism elicited in response to WSSV infection, we carried out the transcriptome analysis using the hepatopancreas of black tiger shrimp *Penaeus monodon* (Fabricius) at moribund stage of WSSV infection.

The generation of transcriptome from hepatopancreas of control and WSSV infected shrimp resulted in 67.17 million and 68.73 million raw reads respectively. The de novo assembly of the shrimp transcriptome generated 45437 contigs. A total of 15758 (~37 %) transcripts from control shrimp and 18251 (~40 %) transcripts from WSSV infected shrimp could be annotated. In both the transcriptomes, the highest number of unigenes belonged to molecular functional category, relating to ATP binding. The other maximum unigenes belonged to proteolysis and proteins integral to membrane representing biological process and cellular component functional categories. The differential gene expression analysis from WSSV infected shrimp transcriptome revealed 424 up regulated and 226 down-regulated genes. The gene expression analysis showed up- regulation for important immune genes such as C-type lectin, clip domain serine proteinase 2, caspase- 3, prophenoloxidase-activating enzyme 2a, nitric oxide synthase and serine proteinase inhibitor 6 genes. The transcriptome data of the WSSV infected shrimp provide molecular insights into the host response and identification of *Candida*te immune genes in response to WSSV infection for genetic improvement of high health shrimp.

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Variability of reproductive performance of females of *Penaeus monodon* : a histological perspective

Mohanlal, D. L., C. P. Balasubramanian*, J. R. Merlyn, K. K. Vijayan, Sherly Tomy and C. Gopal
Central Institute of Brackishwater Aquaculture, 75 Santhome High Road, Chennai 600 028, India.
Email: cpbalasubramanian@yahoo.com

The major limiting factor for the commercial breeding program of *Penaeus monodon* is the reproductive dysfunction of shrimps under captivity. Intraspecific variability in reproductive performance in penaeid females has been hypothesized. In order to test this hypothesis and further provide insight into the reproductive mechanism of penaeids, ovarian cycle and oocyte development of naturally reproducing and endocrinologically manipulated (eyestalk ablated) females were studied by light and electron microscopy. Female germ cells were categorized into seven developmental stages comprising oogonial cell stage and six primary oocyte stage (Oc1 to Oc6). Oogonial cells were far less found in the wild broodstock contrary to the previous studies, and it indicates that before reaching the broodstock size, oogonial cells may have reached into the meiotic prophase. Absence of microvilli in any of the TEM section confirms the autosynthetic vitellogenesis in penaeids. Three groups of wild broodstocks were able to be recognized in the eyestalk-ablated groups: 1) Females readily responding to eyestalk ablation, 2) females had long latency after eyestalk ablation and 3) female never spawned after eyestalk ablation. In the first group, females showed synchronous and homogenous development identical to the naturally reproducing wild caught animals whereas in the second group, development of oocytes were asynchronous and almost similar to the pond reared females. This study suggest that, while selecting founder population for selective breeding, post larvae originated from the first group of broodstock that are readily responding to eyestalk ablation should be selected.

Production of multiple enzymes from marine isolate using leather industry solid waste for the degradation of multiple industrial wastes

Bhargavi, G*, Pritish Ranjan and K. Ramani
Department of Biotechnology, School of Bioengineering, SRM University, Kattankulathur, Kanchipuram Dt., Tamilnadu 603 203, India. Email: bhargavaa23@gmail.com

A huge amount of proteinaceous and lipidic liquid and solid wastes are being generated every year in India from various industries. Such wastes have to be

treated before its release into natural water bodies, mainly oceans, for protecting the aquatic ecosystem. Enzymatic hydrolysis is being considered world-wide as an eco-friendly method when compared to the conventional acidic and alkaline hydrolysis methods. Enzymatic hydrolysis is also an advantageous approach because it can be performed at lower temperature to save energy, and exhibits high selectivity, leading to products with high purity and fewer side products. From the economical point of view, the production of multiple enzymes from single source may be considered as an advantageous technology instead of producing single enzyme from single source. Literature already exists on the production of proteases and lipases from different sources and from different strains for industrial applications. In the present study, marine strains isolated from benthic sediments, that are capable of producing multiple exo-enzymes were used. Since the leather industry solid waste, animal fleshing (ANFL) is considered to be highly rich in protein and lipids, it was used as the substrate for the growth of the isolates and for the production of multiple enzymes such as protease and lipase. The produced enzymes were partially purified from the fermented medium using ammonium sulfate precipitation and dialysis. The partially purified enzymes were immobilized onto Mesoporous activated carbon (MAC). The multiple enzymes (ME) immobilized MAC (MEMAC) were characterized for their morphological and functional group analysis. The MEMAC was used as a biocatalyst for the degradation of synthetic mixed protein and lipid sources. The study showed MEMAC is a potential biocatalyst for the degradation of multiple industrial wastes including proteinaceous and lipidic wastes from the fish or marine processing industry.

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MECOS 2 |MBTO 04

In vitro explant cultures of different molluscan tissues

Suja, C. P. * and S. Dharmaraj
Central Marine Fisheries Research Institute, Tuticorin Research Centre, South Beach Road, Tuticorin 628 001, Tamil Nadu, India. Email: cpsuja@gmail.com

In vitro culture studies are very limited in marine invertebrates. Molluscan cells in culture would provide valuable research tools in the study of molluscan diseases, nutrition and biochemistry. *In vitro* nacre formation was reported from the pearl oyster, *Pinctada fucata* and the abalone *Haliotis varia*. The present study aims for understanding a common culture system for molluscan cell culture studies. Hence experiments were done with different molluscan tissues and cell characteristics were studied.

Pinna and *Modiolus* species were collected from the landing centres of Vallappatti, Tuticorin. Animals were thoroughly cleaned and brought to the Tissue culture laboratory of Tuticorin Research Centre. The animal was given thorough cleaning in sterile sea water and surface sterilized by 70 % ethyl alcohol before removing the mantle tissue. The mantle strips were then treated in antibiotic solution of 1000 μg/ml streptomycin and 2000 IU/ml of penicillin. Again the strips were washed in sterile sea water twice and cut into small pieces of 2mm^2 size explants. Three

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ml of Medium 199 with 25 % supplementary salt solution and 10 % FCS was used for each T25 culture flask. Cultures were incubated at 28° C and pH 7.4. Cells were observed after 24 hrs. Granular and agranular cells were noted from both the cultures and recorded the cell size. Granular cells of 3- 20 μm & 2- 10 μm size and agranular cells of 10- 20 μm &15- 22 μm size were released from the explant cultures of two species of *Pinna*. Granular cells of 3- 10 μm size and agranular cells of 10-20 μm size were released from the explants of *Modiolus* sp. The cultures were maintained for one month. Attempts were also made with different types of tissues like heart, gills, hepatopancreas and mantle of *Pinctada margaritifera* early in 1998 with a single animal bought from Andamans. Few round cells were liberated from the mantle and gills after 24 hrs. But the size could not be recorded from these cultures due to contamination. Numerous round cells were liberated from the hepatopancreas culture where the cells were recorded as 10- 20 μm size with an average size of 16 μm. Fibroblast cells were also noted in cultures on 3rd day. Cell characteristics from *Pteria* sp. and *Perna viridis* were already reported separately. The major problem of contamination in molluscan cell cultures was controlled after the use of T25 flasks from petriplates. The successful achievement of cell proliferation in various molluscs under the above culture conditions proved the viability of this culture system. The *In vitro* technology now developed at CMFRI can be extended to any mollusc and can be utilized for various applications of molluscan cell culture studies.

Evaluation of optimum protein: energy requirement in formulated feeds containing marine proteins for growth, maturation and breeding of *Trichogaster chuna*, the honey gourami

Mithun Sukumaran, Vijayagopal Pananghat* Kajal Chakraborty and Diana Pek Sian Chan
Applied Science School, Temasek Polytechnic, 21 Tampines Avenue 1, Singapore 529 757.
Email: vgcochin@hotmail.com

Reports on gross nutritional requirements of gouramis were restricted to two species, namely, blue gouramis, *Trichogaster trichopterus* (= *Trichopodus trichopterus*) and Trichogaster alius. As the information available in the public domain is inadequate for providing complete nutritional solution for honey gourami *Trichogaster chuna* a nutritional evaluation of protein: energy ratios appropriate for growth and breeding of honey gourami was taken up. Gross protein and fat requirement in formulated feeds designed for honey gourami was determined using feeds containing protein at 30, 40 and 50% level with a fat of 6% and 9% at each level of protein. All ingredients used in formulation of feeds were natural with fishmeal, shrimp meal, clam meal, soy flour and wheat flour providing protein and energy and an equal mixture of fish oil (crude sardine oil) and groundnut oil providing fat. The formulation was fortified with minerals, vitamins and additives like *Spirulina* and mixed carotenoids.

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Amino acid and fatty acid profiles of feeds indicated no gross insufficiencies. Whole body amino acid profiles when compared before and after the dietary treatments indicated decline of all amino acids except for methionine and lysine. Fatty acid profiles of the whole body when compared with initial profiles showed a marked increase only in case of monounsaturated fatty acids. No significant differences were observed (P>0.05) between dietary treatments. Feeds with 30% protein and 6% fat were sufficient for normal growth. Feeds with 40% protein and 6% fat were required for accelerated growth and reproduction.

In the light of the reports available and based on our work, our contention is that 30% protein and 6% fat is sufficient in the feeds of *T. chuna*. However, to attain fast sexual maturity and breeding, 40% protein and 6% fat would be appropriate because the first natural spawning incidence happened in this treatment which was eventually the treatment in which growth was faster. Our observation is that *T. chuna* being the smallest of the gouramis in terms of body size compared to the other species discussed, their growth is slow and maturation is faster. Gouramis in general are reported to reach a marketable size in 120 days. *T. trichopterus* is reported to mature in 12-14 weeks. All these milestones were observed to be faster in this species where, from a marketable size of approximately 1.3 g sexual maturation could be observed by time the fish becomes 2.2 g in size. Based on these observations we conclude feeds with 30% protein and 6% fat to be suitable for maintenance of these fish. For achieving sexual maturation and spawning feeds with ≥40% protein and ≥6% fat should be used. Needless to say the quality of feed ingredients used should be at par with that meant for human consumption with all additives included in the formulation. The present investigation revealed that scientifically formulated feeds with 30 % protein and 6 % lipid is sufficient for aquarium keeping of honey gourami. For development into brood stock and volitional spawning of honey gourami, ≥40% protein and ≥6% lipid is essential.

MECOS 2 |MBTO 06

In vitro and *In vivo* screening of the antagonistic bacteria *Bacillus subtilis* MBTD CMFRI Ba37 and *Pseudomonas aeruginosa* MBTDCMFRI Ps04 for use as biological disease control agents in aquaculture

Anusree, V. Nair*, M. Leo Antony and K K. Vijayan
Central Marine Fisheries Research Institute, Kochi 682 018, Kerala, India.
Email: anuadithya2004@gmail.com

Aquaculture is one of the fastest growing food production sectors and supplies nearly fifty percent of the world fish food production. Disease outbreaks due to pathogenic bacteria have become a major disease problem in aquaculture rearing systems. The use of antibiotics, synthetic drugs, disinfectant like compounds and chemicals in aquatic environments are widely criticized for their negative effect on environment and also on the consumer. Hence, the need of the hour is to develop

an eco-friendly approach to tackle the bacterial disease issues in aquaculture. In recent years, the use of probiotics as biological control seems to be a potential alternative for antibiotics in aquaculture. In this perspective, the identification and introduction of bacteria with antagonistic activity against pathogens into aquaculture system has proven to be a more effective disease control strategy. Our previous studies reported that the genus *Bacillus* and *Pseudomonas* were the common groups that possess significant antagonistic activity against aquaculture pathogens.

The present study evaluated the *In vitro* and *In vivo* antagonistic effect of the two potential antagonistic bacteria - *Bacillus subtilis* MBTDCMFRI Ba37 and *Pseudomonas aeruginosa* MBTDCMFRI Ps04 for use in aquaculture as preventive measures against Vibrio infections. These two bacteria were isolated from tropical estuarine habitats of Cochin and screened for antagonistic activity against aquaculture pathogens. The cultured and filtered supernatant of *B. subtilis* Ba37 and *P. aeruginosa* Ps04 exhibited higher inhibitory activity against *Vibrio vulnificus* MTCC1145, *V. anguillarum* 01, *V. harveyi* 101 and least activity against *Aeromonas hydrophila*. The zone of inhibition against the tested pathogen by disk diffusion method was around 9- 22 mm (Fig 1). The *Candida*te bacteria evaluated for inhibitory potential by co-culturing assay, has revealed that *B. subtilis* Ba37 and *P. aeruginosa* Ps04 were inhibitory to *V. anguillarum* 01 and *V. harveyi* 101 respectively Fig.1. Antagonistic activity of *B. subtilis* MBTD CMFRI Ba37 and *P. aeruginosa* MBTDCMFRI Ps04 by disc diffusion method. A - *Vibrio vulnificus* MTCC1145; B - Vibrio parahaemolyticus MTCC 451; C- Aeromonas hydrophila; D - Vibrio alginolyticus 101; E- *Vibrio harveyi* 101 and F- *Vibrio anguillarum* A1. The measurement indicates the inhibition zone (mm) formed around the isolates. The values may differ ± 1mm from the size mentioned Fig .2. Co-culture assay of *P. aeruginosa* MBTDCMFRI Ps04 against *V. harveyi* 101. Tubes showed the results of co-culture assay- *P. aeruginosa* MBTDCMFRI Ps04 inhibits the growth of *V. harveyi* 101. Yellow colour indicates the growth of *V. harveyi* 101 whereas green indicates the inhibition. even at 104 CFU/ml concentrations (Fig. 2). On evaluating the pathogenicity of antagonistic strains, *B. subtilis* MBTDCMFRI Ba37 and *P. aeruginosa* MBTDCMFRI Ps04 were found to be safe and did not cause any infections by intramuscular injection into ~5 g of sub-adults of *Etroplus suratensis* at concentration range from 106 to 109 CFU ml^{-1}.The results of this study illustrated that *B. subtilis* Ba37 and *P. aeruginosa* Ps04 were found to be

Fig.1. Antagonistic activity of *B. subtilis* MBTD CMFRI Ba37 and *P. aeruginosa* MBTDCMFRI Ps04 by disc diffusion method. A - *Vibrio vulnificus* MTCC1145; B - *Vibrio parahaemolyticus* MTCC 451; C- *Aeromonas hydrophila*; D - *Vibrio alginolyticus* 101; E- *Vibrio harveyi* 101 and F- *Vibrio anguillarum* A1. The measurement indicates the inhibition zone (mm) formed around the isolates. The values may differ ± 1mm from the size mentioned

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Fig .2. Co-culture assay of *P. aeruginosa* MBTDCMFRI Ps04 against *V. harveyi* 101. Tubes showed the results of co-culture assay- *P. aeruginosa* MBTDCMFRI Ps04 inhibits the growth of *V. harveyi* 101. Yellow colour indicates the growth of *V. harveyi* 101 whereas green indicates the inhibition.

promising *Candida*tes that could be employed as potential antagonistic bacteria in aquaculture systems for the management and control of bacterial infections. Further studies on these bacteria will allow their utilization as live or inactivated biological disease control agents in aquaculture to control bacterial diseases.

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MECOS 2 |MBTO 07

Molecular identification of barracuda (Perciformes, Sphyraenidae) from Indian waters

Jena, J. K., V. S. Basheer*, K. K. Bineesh, E. M. Abdussamad, T. B. Ratheesh, C. Mohitha, K. V. Akhilesh, A. Gopalakrishnan
National Bureau of Fish Genetic Resources, Kochi Unit, Central Marine Fisheries Research Institute Campus, Kochi 682 018, Kerala, India. Email: vsbasheer@gmail.com

The barracuda is a marine ray - finned pelagic predatory fish of the genus *Sphyraena*, the only genus in the family Sphyraenidae. They are found in tropical and subtropical regions worldwide and may hold an important position as an apex predator in near shore systems. Globally there are more than 22 species of barracuda, that size range from less than 50cm to nearly 2 meters in length. The species belonging to this genus accounted one of the major highly priced commercial fishes that caught by Indian pelagic fishery. Its estimated landing of 25,269 tonnes in 2014 accounted for 0.67 % of the total marine fish landings in the country (CMFRI, 2014). So far ten species has been reported from Indian waters viz., *Sphyraena barracuda, S. jello, S. putnamae, S.qenie, S. forsteri, S. obtusata, S. chrysotaenia, S. iburiensis, S. acutipinnis* and *S. novahollandae.* Apart from that, recently a putative new species was also encountered from the Arabian Sea.

To identify this species we used mitochondrial marker gene cytochrome-C oxidase subunit I. Worldwide mitochondrial DNA bracode is being used for identification of new species (www.BOLDsystems.org). The mitochondrial marker gene cytochrome-C oxidase subunit I (CO1/COX 1) is having fast mutation rate enough

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to differentiate closely related species. In the present study, the sequences of COI were determined from 35 individuals of seven species, which include putative new species of Sphyraenidae from Indian waters to identity species and phylogenetic relationship. Sequencing of the COI gene produced an average of 652 nucleotide base pairs. Insertions, deletions and stop codons were absent in all the sequences. Outof the 652 sites, 371, 189, 128 and 61 were monomorphic, polymorphic, parsimony informative and singleton respectively.The nucleotide frequencies are 24.40 % (A), 29.80 % (T), 27.70 % (C), and 18.10 % (G). The Si/Sv ratio was found to be 2.58. The overall mean genetic distance value was 0.211. The mean genetic distance between all the seven species was calculated (Table 1). The NJ tree based on K2P genetic distances were created to provide a graphic representation of the patterns of divergences (Fig. 1). The haplotype diversity and nucleotide diversity was found to be 1.000 and 0.15149 respectively.Based on COI neighbour-joining tree the suspected new *Sphyraena* sp. positioned very closely with *Sphyraena barracuda*, but the average Kimura two-parameter (K2P) genetic distance between these two species was 12 %, which is in the range for congeneric species (Ward *et al.*, 2009) and thus more further sampling from wide localities is initiated for further morphological and molecular studies on this putative new species. Partial sequences of COI gene provided phylogenetic information to distinguish the seven Indian species of barracuda indicating the usefulness of molecular markers in species identifications and can be used for developing catch verification programme for sustainable fishery management and conservation.

Table 1: Mean genetic distance between seven species of the familySphyraenidaeusing mitochondrial COI gene.

	SPPU	SPQE	SPBA	SPJE	SPSPA	SPAC	SPCH
SPPU							
SPQE	0.230						
SPBA	0.170	0.195					
SPJE	0.168	0.152	0.143				
SPSPA	0.161	0.196	0.120	0.140			
SPAC	0.278	0.315	0.260	0.248	0.292		
SPCH	0.312	0.297	0.297	0.334	0.306	0.350	
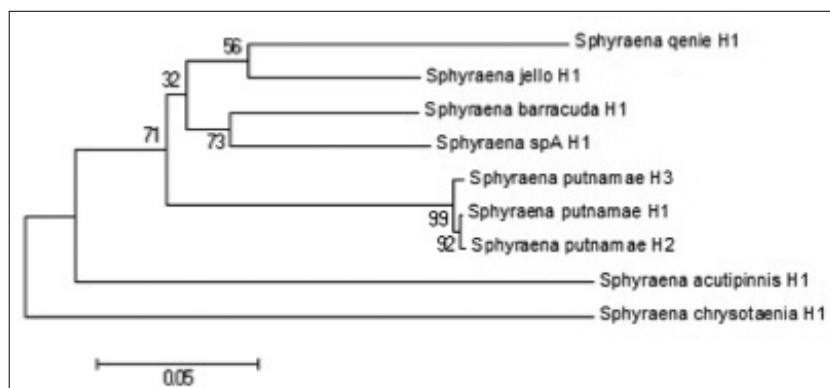
Fig. 1 NJ tree of COI gene sequences derived from seven fish species using K2P distances

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Bioprospecting coastal mangrove metagenome for exploring potential cellulase genes

Asha, P. * and I. S. Bright Singh
National Centre for Aquatic Animal Health, Cochin University of Science and Technology, Kochi 682 016,
India. Email: haiashahere@gmail.com

The mangrove ecosystem is the second most productive ecosystem and an unexplored source for biotechnological/bioprospecting applications. It is a unique environment suitable for cellulase exploration because of the continuous deposition of lignocellulosic biomass in the form of leaf litter. Accordingly, this study was aimed to assess the novel cellulolytic activities of uncultured microbiota present in the sediment from a mangrove region located in Valanthacaud near Cochin estuary.

Sediment samples were collected from Valanthacaud Island, one of the unperturbed patches of mangrove vegetation with rich biodiversity. A direct method of DNA extraction has been standardised for the effective recovery of DNA from the sediment samples. Depending upon the soil type and sampling site, four different kinds of DNA extractions (Proteinase K based soft lysis, harsh lysis using liquid N_2 , Polyvinyl polypyrrolidone - polyethylene glycol, agarose plug DNA extraction) were considered for the sample. The size fractionation of the metagenomic DNA using Pulse Field Gel Electrophoresis (PFGE , CHEF Bio-Rad) has revealed that Proteinase K based method provided better yield than the other three methods. Polyvinyl polypyrrolidone- polyethylene glycol method yielded high purity DNA. Agarose plug embedded DNA extraction yielded DNA in the size range of 267 kb. Liquid N_2 grinding was also a good method for getting high molecular weight DNA without any severe shearing. For all extractions except agarose plug DNA extraction, the sizes of the DNA fragment was in the range of 24 to 45 Kb. DNA purification was standardized with Q-Sepharose (Sigma) as evaluated by the percent reduction in humic acids and percent loss of DNA. A reduction of 70 % to 96 % humic acids was noticed in different dilutions of metagenomic DNA. Prokaryotic 16S rRNA genes could be successfully amplified at 10 fold dilution of the metagenomic soil DNA (125 ug/ml) and it also showed that metagenomic DNA isolated from Valanthacaud mangrove contained relatively low concentration of PCR inhibitory substances. Restriction digestion of the sample DNA was standardized to obtain desired sized DNA (4Kb to 10 Kb) for inserting into the Lambda ZAP express vector system (Agilent Technologies). Size of the primary library was $1.7x10^4$ pfu/ml and it was amplified to get a stable secondary phage library ($2x10^6$ pfu/ml).

Of the 7000 clones screened, a lambda clone carrying 6 kb genomic fragment was able to show yellow clearance zone on Luria Bertani agar plate containing 0.5 % carboxymethyl cellulose (CMC) as substrate. A PCR screening approach was developed using a multiple primer set containing a conservative domain for cellulase gene and amplified from the phagemid DNA isolated from the positive clone. Subcloning of the partial gene showed 90   % similarity on the amino

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acid level with the GH9 cellulase gene from an uncultured clone. Accordingly, this PCR screening approach has been found to be a suitable short cut method for detecting and amplifying cellulase gene sequences from the large genomic construct libraries. Thus the novel catalytic activities of cellulases can be identified from uncultured microorganisms through metagenomical approach that suit different industrial applications and may provide an efficient solution to the economical barrier for cellulose utilization.

Therefore, this study highlights the importance of uncultured biota found in mangroves and to exploit them as novel biotechnological tools for the degradation of cellulose.

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MECOS 2 |MBTP 01

Assessment of nutritional quality of the marine isolate *Candida* MCCF101 as dietary feed supplement to enhance growth of koi carp (*Cyprinus carpio-haematopterus*)

Sunitha Poulose * and I. S. Bright Singh

National Centre for Aquatic Animal Health, Cochin University of Science and Technology, Fine Arts Avenue, Kochi 682 016, Kerala, India. Email: sunitha_paul@yahoo.com

Proper nutrition is one of the most important factors influencing the ability of cultured organisms to attain the genetic potential of growth, reproduction and longevity. In aquaculture nutrition, it becomes absolutely essential to supply feed to meet the nutritional requirements for enhanced growth and productivity. This is because naturally available aquatic food may make a relatively small contribution to the total protein and energy requirements of the cultured fish, and this deficiency is made up with supplementary feeds. Feed supplements are expected to provide proteins, lipids, carbohydrates and energy as well as vitamins and micro and macro nutrients to enable fish to remain free from stress and diseases. Therefore, inevitably, increase in fish biomass in culture systems become increasingly dependent on the supplementary feed. In this context, microbes as feed supplements produced through biotechnological processes have been actively investigated as alternative or unconventional feed supplements for aquaculture and aquaculture systems.

Single cell proteins (SCP), including yeast and bacteria, have been viewed as promising substitutes for fishmeal in fish diets. Various species of yeast and different yeast-containing products have been fed to fish for an assortment of reasons. Yeast protein is known for its easily digestible nutritious value and has been widely used as an animal and aquaculture feed supplement.

Marine yeasts have been regarded safe from the nutritional point of view showing beneficial impact on growth and survival of finfish and shellfish. Commercial feeds

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containing SCP from marine yeasts with high protein content and substantial quantities of other nutrients are still lacking. However, over the years, marine yeasts have been gaining increased attention in animal feed industry due to their nutritional value and immune boosting property.

A marine yeast isolate *Candida* MCCF101 was investigated in the present study to enhance growth performance and feed utilization of koi carp. The yeast contained 30 ± 1.63 % proteins, 36.25 ± 1.25 % carbohydrates, 1.52 ± 0.04 % lipids, $12.05°\pm0.05$ % nucleic acid, 10.05 ± 0.50 % dietary fibers and 6.67 ± 0.94 % ashes. It contained 16.16 % total free amino acids with considerable amount of essential amino acids (valine, isoleucine, phenylalanine, histidine, methionine, arginine, threonine, lysine and leucine) and polyunsaturated fatty acid (linoleic acid). In order to determine the growth performance and feed utilization, fishes were fed with diet containing live and inactivated yeast. Yeast incorporated feed was given twice daily at a rate of 10 % body weight. Growth parameters such as weight gain, specific growth rate (SGR), feed efficiency (FE), feed conversion ratio (FCR), total protein intake (PI) and Protein efficiency ratio (PER) were measured for a period of three months. Growth performance and feed utilization increased significantly ($P< 0.05$) by feeding live yeast than inactivated yeast. All these qualities lead us to recommend *Candida* MCCF101 as a feed supplement in aquaculture especially to Koi carp.

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MECOS 2 |MBTP 02

Fatty acid composition of selected species of cephalopods in the south western coast of India

Soumya, M. K.*, Kajal Chakraborty and P. Vijayagopal
Central Marine Fisheries Research Institute, Kochi 682 018, Kerala, India. Email: sowmyakc.kc@gmail.com

Cephalopods are considered as one of the predominant marine fishery resources. They belong to phylum mollusca and include some interesting members like squids, octopods, cuttlefishes etc. Declining catches in many traditional fisheries and with the introduction of trawling, cephalopod exploitation experiences new strides. Cephalopod catches have increased steadily in the last 40 years, from about 1 million metric tonnes in 1970 to more than 4 million metric tonnes in 2007 (FAO, 2009) and the share of cephalopods in world fish trade was 4 percent in 2010. Their nutritive qualities along with rich taste have increased the value of cephalopods in the world market, and are earning good foreign exchange through export.

Dietary fatty acids, especially the long chain *n*-3 and *n*-6 PUFAs, such as eicosapentaenoic acid (EPA, 20:5*n*-3) and docosahexaenoic acid (DHA, 22:6*n*-3) have recently been proved to have properties that could prevent cardiovascular diseases and inflammatory disorders including type 2 diabetes mellitus, rheumatoid arthritis, cancers, and psychiatric disorders. The synthesis of these long chain unsaturated fatty acids in the body are inefficient, and are not enough to meet the

needs. Hence, these nutritionally important fatty acids need to be supplemented from external sources through the diet. They are found to be abundantly available in marine organisms especially micro algae, finfishes and shellfishes.

The present study was undertaken with an objective to carry out a detailed fatty acid profile of some commercially important cephalopods available along the south western coast of India (Kerala State) bordering the Arabian Sea. The selected species included Octopus membranaceous, *Loligo duvacelii*, and *Sepia pharaonis*. The study demonstrated that these cephalopods are rich sources of long chain PUFAs (43-50 %) especially EPA and DHA, which have pluralities of beneficial effects towards human health. The PUFA content was 50 % in both *L. duvacelii*, and *S. pharaonis* while it was 43.35 % in *O. membranaceous*. The level of saturated fatty acids was significantly lower (28- 35 % TFA, p<0.05) when compared with the PUFAs. The level of SFA accounted for only 28.53 % in *S. pharaonis* and in *O. membranaceous* and in *L. duvacelii*, its account was 35 %. The *n*- 3/*n*-6 ratios in these species were found to be significantly higher (3.4- 11, p<0.05) than the required recommended level of 1- 2, and therefore, these may be the ideal *Candida*te species to counter the greater intake of *n*-6 fatty acids through our vegetable based edible oil. The lower atherogenicity index and thrombogenicity index (0.4 - 0.7 and 0.17 - 0.2 respectively) values obtained during the study highlights the anti-atherogenic and anti-thrombogenic potential of the edible part of cephalopods. The PUFA/SFA value for cephalopods was found to be greater (1.21- 1.76) than the recommended minimum of 0.45. The current study concludes that cephalopods contains more PUFAs and can be treated as an alternative to the conventional food stuffs for obtaining the same for a healthy life.

(A) Percent composition of fatty acids and (B-D) Nutritional indices of the cephalopod species
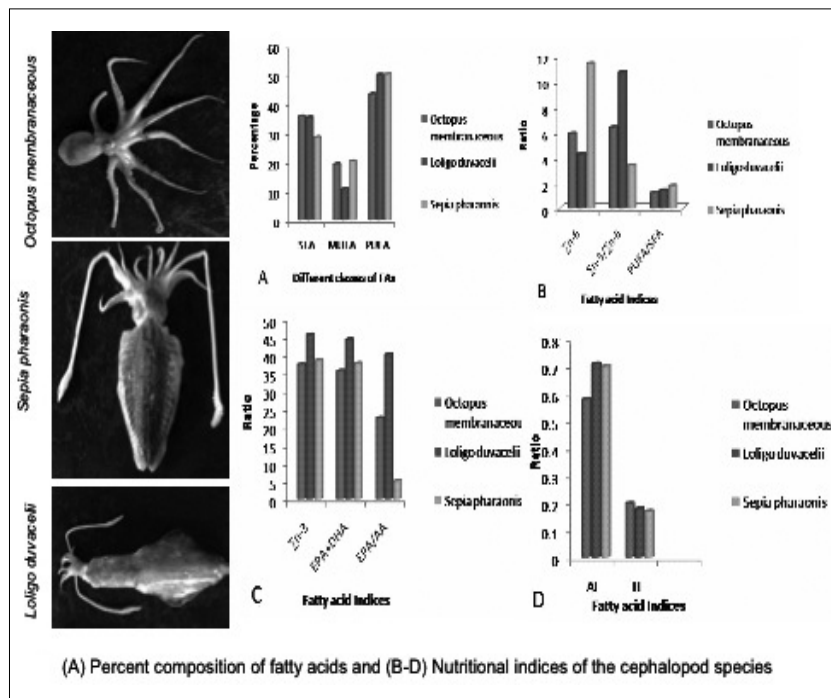
Nutritional composition of the black clam, *Villorita cyprinoides* (Family, Corbiculidae)

Minju Joy*, Kajal Chakraborty and P. Vijayagopal

Central Marine Fisheries Research Institute, Kochi 682 018, Kerala, India. Email: minjujoy@gmail.com

Bivalve molluscs form a major seafood in the coastal part of India and clams contribute an important share. Mollusks are one of the large invertebrate groups in freshwater habitat. The black clam, *Villorita cyprinoides* (Family, Corbiculidae) is one of the most common seafoods in the coastal regions of India. Its main source is the Vembanad Lake (9° 35' N and 76° 25' E), which is a major estuarine system along the southwest coast of India bordering the Arabian Sea. This estuarine system has been reported to harbour rich resources of clam species. They are also exploited widely for both meat as food and shell as an important source of raw material for industrial applications. Molluscs are reported to posses many essential nutritional elements, which are generally not present in our staple food items, such as cereals and pulses. The nutritional supplements available in the market are generally costly and common people cannot afford to meet the expenditure. Clams are reported to have greater nutritional value and digestibility. The bivalve

(A) Fatty acid composition of *V. cyprinoides* (% TFA), (B) fatty acid ratio, (C) Collection site of *V. cyprinoides* (natural habitat at Vembanad Lake 9°35' N and 76° 25' E) (Inset: *V. cyprinoides*)
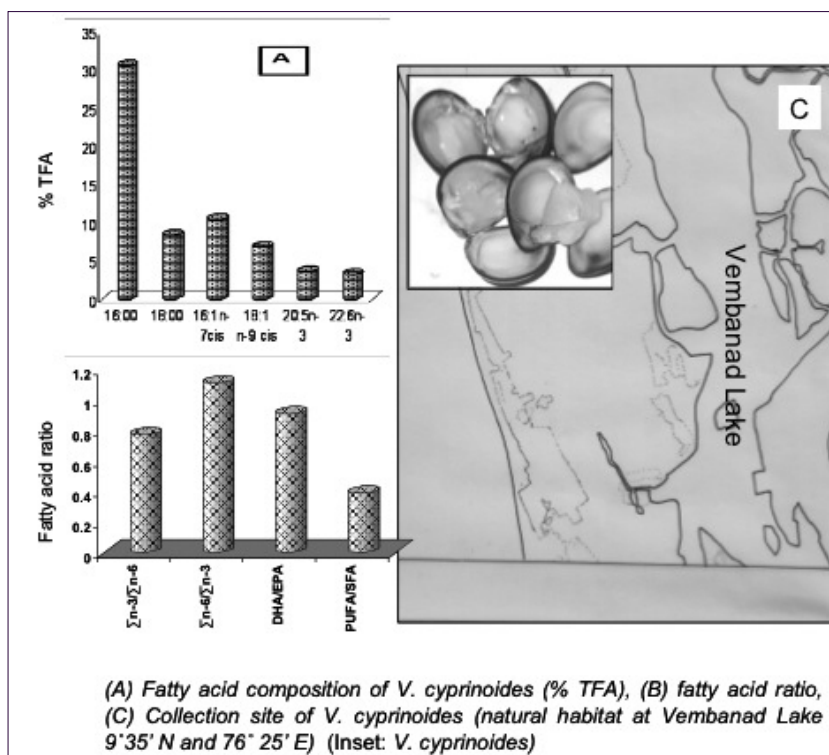
clams were evaluated for their nutritional composition, so that they can effectively substitute other terrestrial sources.

Biometric measurements of clams were determined by measuring length, width and thickness of clam and condition indices calculated as per Imai-Sakai (1961), Booth (1983) and Walne (1976) methods. Proximate composition, cholesterol, lipid and protein content were evaluated by AOAC (1990), Rudel & Morris (1973), Folch (1957) and Lowry (1951) methods, respectively. Estimation of minerals was carried out by AAS following di-acid digestion method and fat soluble vitamins by Salo-Vaananen (2000) method (HPLC). Phosphorus and Vitamin C were quantified by the method of AOAC. FAMEs technique was used for fatty acid analysis (GC).

V. cyprinoides showed higher meat yield (22 %) and showed good condition indices. Black clam exhibited higher lipid (8.7 %) and cholesterol (56mg/100g) content. Clam meat was found to be rich in macro and micro nutrients. K and P concentration in *V. cyprinoides* were found in appreciable quantities (60.2 & 534.2 mg/100g wet weight). The Ca+P content were significantly greater for *V. cyprinoides* (562.7 mg/100g wet weight), which is essential for preventing demineralization of bones. The micronutrients Fe and Zn content in the clam were about 5.6 and 3.3 mg/100g wet weight, respectively. The vitamin A and D3 content was found to be 41 and 183 IU/100g wet weight, respectively for this species which is essential for preventing osteoporosis in adults. The antioxidant vitamins E and C contents in *V. cyprinoides* were found to 0.32 and 11 IU/100g wet weight, respectively. Vitamin K content in *V. cyprinoides* was found to be 0.7μg/100g.

V. cyprinoides showed higher content of total SFAs (48 %) and lower content of total MUFAs (25.6 %). The content of fatty acid C16:0 was higher in *V. cyprinoides* and contributed 64 % of the total SFA content. The content of C16:1*n*-7 fatty acid in *V. cyprinoides* contributed 41 % to the total fatty acids. Total PUFA content recorded in *V. cyprinoides* was about 18.5 %. EPA contributed 19 % to the total PUFAs in the clam species. The ratio of *n*- 3/-6 PUFA was 0.77 for *V. cyprinoides* and it showed higher DHA/EPA, PUFA/SFA and *n*-3/*n*-6 ratio. The relatively greater level of DHA and EPA appeared to be an inherent quality of these species. Figure showed comparison of *n*- 3/*n*-6, *n*-6/*n*- 3, DHA/EPA, and PUFA/SFA in *V. cyprinoides*.

The UK Department of health recommends an ideal ratio of *n*-6/*n*- 3 to be maximum 4.0 and the values higher than 4.0 are considered harmful to health and may lead to cardiovascular diseases. The *n*-6/*n*- 3 ratio of *V. cyprinoides* was found to be less than 2. The relatively greater level of DHA and EPA appeared to be an inherent quality of these species. The consumption of bivalve molluscs also provides an inexpensive source of protein with high biological value, essential minerals and vitamins. Due to their nutritional and market value, clam aquaculture has also shown an increase during the past few years. The malnutrition problem in our country can be overcome by the effective utilization of nutrient rich molluscan seafood. From the above observations it is clear that the body tissue of *V. cyprinoides* with rich nutritive value can be used as a regular sea food mainly, in coastal regions of India which promotes nutrients for the people suffering from malnutrition. It is also important for formulating of nutraceuticals in future.

Replacement of dietary fish meal with Cottonseed meal and shrimp head meal in diets of tilapia (*Oreochromis mossambicus*) advance fry

Lende, S. R.*, S. I. Yusufzai, P. J. Mahida, H. Mapwesera, G. Chavda and G. Rana
Department of Aquaculture College of Fisheries, Junagadh Agricultural University, Veraval, Gujarat 362 265, India. Email: lendesmit@gmail.com

Two consecutive feeding experiments were conducted to determine the optimum dietary level of Cottonseed meal and shrimp head meal to replace fish meal (FM) in diets for tilapia (*Oreochromis mossambicus*) advance fry. In experiment-I, tilapia (*O. mossambicus*) advance fry (BW: 0.62± 0.04 g) were fed six isonitrogenous (40 % crude protein) experimental diets viz. control diet (100 % fish meal) and five treatment diets (fish meal replaced with cottonseed meal at 10, 20, 30, 40 and 50 % of dietary protein levels respectively). In experiment-II, tilapia (*O. mossambicus*) advance fry (BW: 0.8± 0.03 g) were fed six isonitrogenous (40 % crude protein) experimental diets which included a control diet (100 % fish meal) and five treatment diets viz. fish meal replaced with shrimp head meal at 10, 20, 30, 40 and 50 % of dietary protein levels respectively. The fishes were fed *ad-libitum* during the experimental period of 60 days. Based on the results recorded from the present experiment, it was found that higher growth, SGR, PER, survival and lowest FCR were obtained by feeding the fish with the diet containing 30 % CSM as well as shrimp head meal. Thus, it was found that Cottonseed meal and shrimp head meal could successfully replace up to 30 % of fish meal in the diet of *O. mossambicus* advance fry.

Fundamental barcode data for *Penaeus monodon* adult, juveniles and *Penaeus semisulcatus* from farms for confirming species status

Jayachandran, K. V. *, P. V. Vipindas, C. G. Rakesh and Devika Pillai
School of Ocean Studies and Technology, Kerala University of Fisheries and Ocean Studies, Kochi 682 506, Kerala, India. Email: chandrankvj@gmail.com

Penaeus monodon Fabricius, 1798 and *Penaeus semisulcatus* De Haan, 1844 are two commercially important penaeid prawns in Indian coasts. *P. monodon* has attained greater significance (accounts for more than 50 % of the world's cultured shrimp) during 2001 but with the introduction of *Litopenaeus vannamei* its share has been reduced considerably.The two species are identified mainly based on the hepatic carina which is nearly straight in the former species and inclined in the

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latter. Apart from this character, *P. semisulcatus* possesses a small exopodite in the fifth pereopod while it is absent in *P. monodon*. During recent times farming of *P. monodon* is gaining momentum. But farmers are complaining about poor growth and also they suspect that the distributed seeds are that of *P. semisulcatus*. This confusion arose because juveniles of the *P. monodon* do possess coloration resembling that of *P. semisulcatus*. In this context, barcode data for *P. monodon* adult and juveniles and *P. semisulcatus* were attempted and found helpful in confirming the species strains and thus generated a fundamental data to avoid such confusion. Moreover this fundamental data may be useful in assuring the quality of brood stock for the production of quality seeds.

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MECOS 2 |MBTP 06

Effect of bacterial heterotrophs on biogeochemistry of the shelf sediments along Kerala coast

Thasneem, T. R*, K. M. Mujeeb Rahiman, M. Movita, A. A. Mohamed Hatha and A. V. Saramma
Department of Marine Biology, Microbiology and Biochemistry, Cochin University of Science and Technology, Kochi 682 016, Kerala, India. Email: thasneem3886@gmail.com

Marine sediment overlay two-thirds of the earth's surface, representing one of the largest microbial habitats on earth. It is complex in nature and acts as the final storage ground for organic input from water column processes. Bacteria that dwell on these sediments account for most of the benthic biomass and play a decisive role in the decomposition as well as production of organic matter and thereby contribute greatly to overall biochemical cycles. They carry half of the primary production on the planet and play a major role in the structure and functioning of the benthic food web. Marine sediments harbour remarkably high density of approximately 109 bacterial cells cm-3, irrespective of ocean depth. Their distribution, structure and activity are strongly affected by a great variety of physical factors such as temperature, sediment type, chemical factors such as organic matter content, quality of organic matter and biological factors such as community structure, level of predation or grazing. Besides these, the composition of benthic microbial communities is strongly correlated with latitude, demonstrating that biogeographic factors are significant determinants of the microbial diversity. In the present investigation heterotrophic bacteria were isolated from 8 transects in the Arabian Sea along Kerala coast (8°32' to 12°50' N; 73°50' to 76°47' E) up to a depth of 1000 m.

Horizontal distribution of culturalable heterotrophic bacteria, nitrogen fixing bacteria, actinomycetes and fungi in the shelf sediments was examined. The bacterial abundance ranged from 3.55 x 105 to 5.32 x 107 cfu/gm for THB and that for nitrogen fixing bacteria from 4 x 102 to 5.56 x 104 per gm wt. of the sediment. A total of 214 isolates were obtained on Zobell Marine Agar (ZMA) media. Thirty strains from Mangalore to Valapad transects were subjected to enzyme analysis by plate assay in ZMA medium and carbohydrate utilization in Mannitol Oxidation
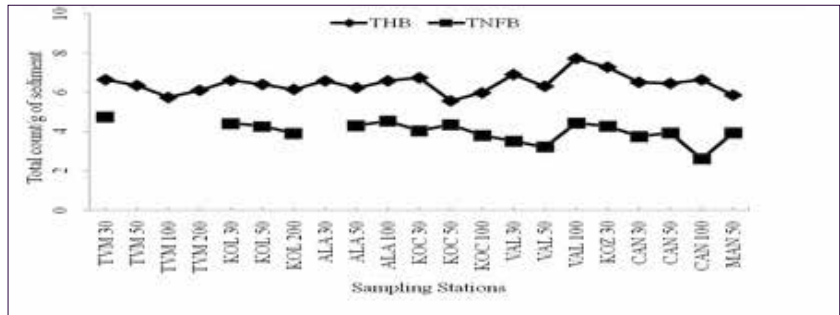
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Fig. 1. Total heterotrophic Bacteria (THB), total nitrogen Bacteria (TNFB), total actinomycetes and total fungi from sediments samples of different transects

Fermentation medium. More than 50 % were glucose fermenters and 71.42 % were citrate utilizers. Among the various hydrolytic enzymes analyzed, ability to produce gelatinase (72.72 %) was frequently encountered, followed by nitrate reductase (63.63 %). Several strains were also capable of producing proteinase (60.6 %), amylase (39.4 %), cellulose (39.4 %), nitrite reductase (39.4 %), carboxy methyl cellulase (36.36 %) and lipase (27.27 %). Fig. 1. Total heterotrophic Bacteria (THB), total nitrogen Bacteria (TNFB), total actinomycetes and total fungi from sediments samples of different transects Fig 2. Results of bacterial isolates towards different carbon source utilization Fig 3. Results of bacterial isolates towards and different type of enzymatic Activity.
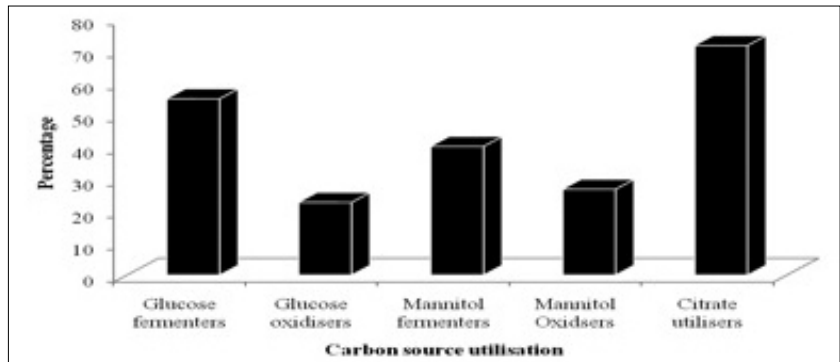
Fig. 2. Results of bacterial isolates towards different carbon source utilization
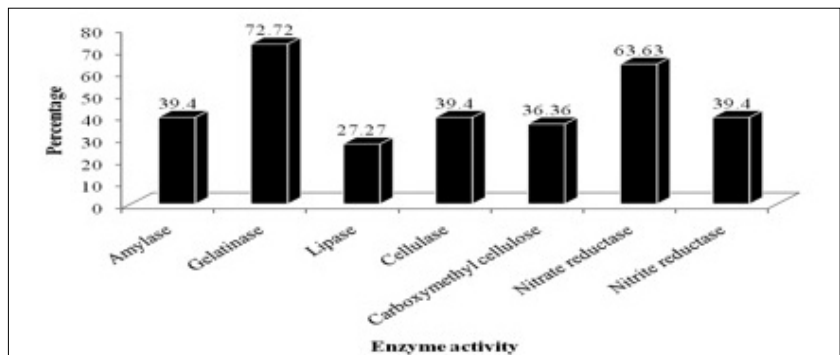
Fig. 3. Results of bacterial isolates towards and different type of enzymatic Activity

Genetic diversity of Indian oil sardine *Sardinella longiceps* evaluated using mitochondrial control region sequences

Sandhya Sukumaran*, Wilson Sebastian, A. Gopalakrishnan, P. U. Zacharia and K. K. Vijayan

Central Marine Fisheries Research Institute, Kochi 682 018, Kerala, India.
Email: sukumaransandhya@yahoo.com

Indian oil sardine, *Sardinella longiceps,* is an important constituent of the Indian pelagic fishery with an estimated annual landing of 6 lakh tons. Small pelagic fishes like Indian oil sardine respond to environmental and climatic fluctuations with seasonal variations in recruitment and abundance. Frequent population collapses and recolonizations will leave genetic imprints on the species which will provide critical insights in to their historical behaviour. Considering the commercial and ecological importance of Indian oil sardine, a detailed study was conducted on the genetic diversity of Indian oil sardine using mitochondrial control region sequences. A 1096 bp portion of the control region was amplified in 274 individuals collected from the distribution range of Indian oil sardine. The samples were collected from Gulf of Oman, Veraval, Mumbai, Mangalore, Calicut, Kochi, Kollam, Trivandrum, Chennai and Vizag. There were a total of 229 haplotypes with a very high haplotype diversity value of 0.99. The most abundant haplotype was found in 4 individuals. There were 239 variable sites with 80 transitions, 30 transversions and 149 singleton sites. The number of parsimony informative sites was 90 with average number of nucleotide differences being 9.65. Average number of nucleotide differences was highest between Mangalore and Vizag (18.9) and Mangalore and Kochi (18.4). Nucleotide diversity value for all sequences was 0.013. Nucleotide diversity values were higher in Mangalore and Calicut (0.022 and 0.020 respectively). This pattern of high haplotype diversity coupled with low nucleotide diversity is characteristic of populations having undergone a demographic expansion after a period of low effective population size. This demographic expansion of sardine populations might also have caused range expansion of Indian oil sardine populations. Periodic extinctions and recolonizations also will produce similar molecular architecture and such events are common in species like Indian oil sardine which occur in upwelling areas.

Genetic diversity of tiger shrimp along the Indian coast

Sivamani Balasubramaniam*, Vinaya Kumar Katneni and Gopalapillai Gopikrishna
Central Institute of Brackishwater Aquaculture, 75, Santhome High Road, Chennai 600 028, Tamil Nadu, India. Email: sivamani@ciba.res.in

In this study, the genetic diversity of tiger shrimps was studied using the partial sequence of cytochrome c oxidase I (CO 1) a mitochondrial gene. Ten samples each from ten different locations i.e. Andamans, Chennai, Kakdwip, Harshad Miyani, Kollam, Mangalore, Paradwip, Ratnagiri, Tuticorin and Vizakhapatinam were used to sequence the cytochrome c oxidase I (CO I) gene using the primers specified by Folmer *et al.*, (1994). The forward and reverse strands of sequence were aligned in BioEdit 7.1.3.0 software to obtain the consensus sequence. Partial CO I gene sequence containing 569 bp was utilized to estimate population specific and inter-population parameters using Mega 6. The region of CO I gene used in the study is AT rich, accounting for about 64 percent of the sequence. The average frequency of four nucleotides were A = 27.85 %, T = 36.03 %, C = 18.39 %, and G = 17.74 %. Most of the observed substitutions in all the stocks were transitions rather than transversions. The overall transition/transversion bias is 15.71. Tests of homogeneity of substitution pattern between sequences confirmed that they have evolved with a similar pattern of substitution. The analysis of molecular variance indicated that most of the variation existing in the stocks of tiger shrimp was due to within-stock rather than between-stock differences. The pair-wise FST values between all stocks were found non-significant which implies that not a single stock is significantly differentiated from other stocks. The Tajima's D values for neutrality test was - 1.28, indicates that the rare alleles are present at low frequencies. The phylogenetic tree constructed by maximum likelihood, neighbour-joining, minimum evolution, maximum parsimony; UPGMA did not classify single separate clad for the sub-populations. The results indicate that none of the stocks of tiger shrimp differ significantly.

First report of isolation of *Photobacterium damselae* subsp *damselae* from diseased cobia reared in net cages and evaluation of virulence properties of extracellular products

Krupesha Sharma, S.R.*, M.A.Pradeep, N. Sadhu, Praveen N. Dube and K.K.Philipose
Central Marine Fisheries Research Institute, Karwar Research Centre, Uttarakannada 581 301, Karnataka, India. Email: krupeshsharma@gmail.com

Marine cage culture is a method of mariculture where high value food fishes are cultured in high density and low volume. In India, commercial cage farming has been concentrated on cobia, Asian seabass and pompano. Bacterial infections have always been a limiting factor for the sustainability of mariculture. *Photobacterium damselae* subsp *damselae*, belonging to the family Vibrionaceae, is a halophilic bacterium normally found in marine waters and sediments. This species has been described as a pathogen causing disease in humans and different fish species like turbot, seabream, rainbow trout, and big eye scad. So far there have been no reports on infection and mortality in cobia (*Rachycentron canadum*) caused by this bacterium. A case of mortality caused by *Photobacterium damselae* subsp *damselae* in cobia reared in open sea cages in the marine farm of the Karwar Research Centre of Central Marine Fisheries Research Institute is described and the virulence properties of its extracellular products (ECP) are evaluated.

The disease was grossly characterized by haemorrhages at the base of the fin and abdominal swelling. Internally, the consistent feature was the presence of yellowish ascetic fluid in the abdominal cavity. The organism isolated from liver, kidney, blood and ascetic fluid was identified by various biochemical tests and confirmed by 16S rRNA sequencing. Further, the pathogen was differentiated from *Photobacterium damselae* subsp *piscicida* using a multiplex PCR for Ure C and 16S rRNA genes. The antibiotic sensitivity test revealed that all the isolates were resistant to Oxacilin and Vancomycin, but sensitive to most of other antibiotics. ECP of the pathogen exhibited phospholipase and lipase activity. It was negative for gelatinase activity. The API ZYM characterization showed both ECP and whole cell bacteria were positive for the presence of 7 enzymes (alkaline phosphatise, esterase, esterase lipase, leucine arylamidase, α-chymotrypsin, acid phosphatise, napthol-AS-BI-phosphohydrolase) and negative for 8 enzymes (lipase, valine arylamidase, cystine arylamidase, α-galactosidase, β-galactosidase, β-glucuronidase, β-glucosidase, α-mannosidase. Further, the whole cell bacteria were also positive for α-glucosidase and N-acetyl β-glucosaminidase. The LD50 studies revealed both ECP and bacteria were lethal to juvenile cobia. SDS-PAGE profile and silver staining revealed that ECP expressed 15 bands wherein compared to bacteria, 3 bands were repressed and two bands were over expressed.

At present nothing is known about prevalence and distribution of this pathogen in Indian coastal waters. *Photobacterium damselae* subsp *damselae* is considered as

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an opportunistic pathogen for many fish species and humans. The first isolation of this species in cobia which is a potential *Candida*te for cage culture in India, reveals that the infection may be an emerging disease in cultured marine fish species in India. Further, the association of this bacterium with scombroid poisoning in humans reflects the seriousness with which this pathogen should be viewed.

MECOS 2 | MBTP 10

Description of a new species of *Auerbachia* infecting *Caranx heberi* in the coastal sea off Cochin

Sanil, N. K, C. P. Binesh*, P. Shamal, P. K. Asokan and K. K. Vijayan
Central Marine Fisheries Research Institute, Kochi 682 018, Kerala, India. Email: shamal666@live.com

A new species of Myxosporean belonging to the genus *Auerbachia* was recovered from a carangid (*Caranx heberi*) from Cochin. The parasite was found inhabiting the gall bladder of the fish. The taxonomic status of the parasite was studied based on the morphology and morphometry.

Morphologically, the spores appeared similar to that of other *Auerbachia* spp. Briefly, the parasite had club-like spores with a broad anterior end, narrow caudal extension and a single elongated polar capsule, opening at the anterior end of the spore. The spores measured on average 16.56 μm in length and 6.96 μm in width. The polar capsule measured 7.2 μm in length and 3.13 μm in width while the polar filament arranged in 5-6 coils measured 52.85 μm when extruded. The caudal extension measured 6.18 μm in length and the caudal extension angle was 140º.

When compared with the other already described species of *Auerbachia*, the spores of the present isolate showed similarities with *A. caranxi* and *A. chlorinemusis*, but still maintained a unique position among them by differing in the morphometrics. Based on the geographical distribution, host species, spore morphometrics and following the systematic strategies adopted for the taxonomy of the genus *Auerbachia*, the present isolate could be considered as a new species. The isolate is herein named as *A. heberi* n. sp. after the specific name of the host from which it was isolated. Though the extent and potential of damage caused by this parasite is not known, the high intensity of infection in the fish host is definitely a cause of concern.

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Molecular cloning, recombinant expression and purification of *Vibrio anguillarum* glyceraldehyde-3-phosphate dehydrogenase: a potential fish vaccine candidate

Pradeep, M. A.*, S. R. Krupesha Sharma, C. S. Subin, Peter Reynold, N. K. Sanil, Esha Arshad, T.V. Arun Kumar, Anusree V. Nair and K. K. Vijayan
Central Marine Fisheries Research Institute, Kochi 682 018, Kerala, India. Email: drpradeepma@gmail.com

Aquaculture is one of the fastest growing food producing sector in the world. Diseases caused by bacteria are one of the major limiting factors for the sustainability of aquaculture production. Infection caused by *Vibrio* spp., which are the normal inhabitants of marine waters, is a major reason for severe economic loss in aquaculture industry. *Vibrio anguillarum* is the most common Vibrio spp. associated with Vibriosis in various cultured and feral fish species as well as crustaceans. Environmental concerns restrict the use of antibiotics in combating the bacterial infection. Hence, use of preventive measures would be more preferred. Vaccination is a cost effective prophylactic measure in controlling diseases and is increasingly becoming an integral part of aquaculture. Vaccines consisting of immunogenic fractions (subunits) can not only induce a higher degree of protection than inactivated whole cell bacteria in fish and other vertebrates, but also does not produce any undesired effect when compared to the adverse immune reactions caused by whole cell vaccines. Glyceraldehyde-3-phosphate dehydrogenase (GAPDH) is a protein that is associated with virulence in several pathogenic bacteria and has been shown to be a potential component for the production of vaccine against many pathogenic bacteria in fish. Subunit vaccine preparation requires large quantities of purified antigenic protein. Hence, heterologous recombinant expression of the antigen using recombinant DNA technology is the most commonly adopted method.

In the present study, a gene coding 37 kDa *V. anguillarum* GAPDH was cloned and sequenced from a pathogenic strain of *V. anguillarum* isolated from infected Asian seabass (Lates calcarifer). The *V. anguillarum* GAPDH showed 85.3, 85, 98.8, 86.8, 85.3 percent identity with *V. alginolyticus*, *V. harveyi*, *V. ordalli*, *V. parahaemolyticus* and *V. vulnificus* GAPDH, respectively (Fig.1). After in-silico translation, the sequences were analysed using bioinformatic tools for their ability to elicit an immune response. GAPDH showed a higher antigenic index (Fig.2) indicating that they are potential antigens, capable of eliciting a strong immune response. The *V. anguillarum* GAPDH gene was recombinantly expressed in fusion with a 6x histidine tag in *E. coli* (BL21) using pET28b expression vector (Fig.3). The recombinant GAPDH protein was purified using immobilized metal ion affinity chromatography (IMAC) (fig.4) followed by final polishing purification using gel filtration chromatography (Fig.5) to obtain a homogenous pure preparation of Recombinant glyceraldehyde- 3-phosphate dehydrogenase (rGAPDH). Due to the high sequence similarity of the *V. anguillarum* GAPDH protein among

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other pathogenic bacteria, use of GAPDH of *V. anguillarum* as a vaccine would impart immune protection in the host against other bacterial pathogens as well. GAPDH can thus be viewed as a multi-purpose vaccine *Candida*te against several bacterial pathogens. The present study has established a scalable methodology for overexpression of rGAPDH in E.coli expression system and purification of rGAPDH using chromatographic methods. The purified rGAPDH can be used for studying the immune protection imparted in various mariculture species and for production of vaccine against disease causing bacteria in aquaculture. Fig.1. Percent Identity and Divergence of GAPDH gene among various pathogenic Vibrios Fig. 2. Antigenic Index of GAPDH of *V. anguillarum* Fig.3. SDS PAGE showing recombinant expression of GAPDH M=marker I=induced total cellular protein U.I = Uninduced total cellular protein Fig. 4. SDS PAGE showing IMAC purification of rGAPDH I=induced total cellular protein M=marker Fig.5. SDS-PAGE showing Gel filtration chromatography of IMAC purified rGAPDH M= marker E1 & E2= purified GAPDH

Fig.1. Percent Identity and Divergence of GAPDH gene among various pathogenic Vibrios

Fig. 2. Antigenic Index of GAPDH of *V. anguillarum*

Fig.3. SDS PAGE showing recombinant expression of GAPDH
M=marker
I=induced total cellular protein
U.I = Uninduced total cellular protein

Fig. 4. SDS PAGE showing IMAC purification of rGAPDH
I=induced total cellular protein
M=marker

Fig.5. SDS-PAGE showing Gel filtration chromatography of IMAC purified rGAPDH
M= marker
E1 & E2= purified GAPDH

Comparative study on the biochemical and immunological properties of skin mucus from three brackishwater fishes

Prem Kumar* T. Rajeshwaran, M. Natarajan and Krishna Sukumaran

Central Institute of Brackishwater Aquaculture, 75, Santhome High Road, Chennai 600 028, Tamil Nadu, India. Email: prem.cife@gmail.com

During the broodstock maintenance of the three brackishwater fish species; Milkfish (*Chanos chanos*) Grey mullet (*Mugil cephalus*) and Asian seabass (*Lates calcarifer*), milkfish were not found to infected by ectoparasites like fish lice, *Argulus* sp. and sea lice *Caligus* sp.under the similar holding. Mullet (*Mugil cephalus*) and seabass (*Lates calcarifer*) species were observed to be susceptible to the parasites. Hence, a possibility of defense mechanism against parasitic invasion was investigated in the epidermal mucus of milk fish, which serves as a mechanical and biochemical barrier. A comparison of the biochemical and immunological properties of epidermal mucus in three species was conducted.

The ions ($Na+$, $Ca2+$, $K+$) assayed were significantly ($p<0.05$) lower in the mucus of milk fish compared to mucus of seabass and mullet. Specific haemolytic and lectin activity in milk fish mucus were significantly higher ($p<0.05$) in comparison to the blood of chicken, sheep and human. In phagocytosis of killed *Bacillus subtilis*, the mucus of milkfish showed a higher percentage of phagocytosis in both macrophage and neutrophil fractions. Lysozyme, alkaline phosphatase and protease activity were highest in the mucus of milk fish than in the mucus of mullet and seabass.The maximum zone of inhibition was shown by the mucus of milkfish against both *Vibrio harveyii* and *Vibrio parahaemolyticus*.

The FT-IR analysis of the sea bass mucus sample was found to contain aromatic primary amines N-H stretch in 3433 cm^{-1}. It also contains isothiocyanate R-N=C=S, Aldehyde R-CHO at 2059 cm^{-1}, alkenes C=C at 1635 cm^{-1}, alkyl halide C-Br stretch at 534 cm^{-1}. The FT-IR analysis of the milkfish mucus was similar to that of seabass. However, the FT-IR analysis of the grey mullet mucus sample showed alcohols and phenols O-H in 3395 cm^{-1} and isothiocyanate R-N=C=S, aldehyde R-CHO at 2058 cm^{-1}, alkenes C=C at 1636 cm^{-1}.

The UV-Vis spectral analysis of seabass mucus revealed the presence of toluene, isoquinoline, 2-furaldehyde, octadecenoic acid, biphenyl, thymidine, cinnamic acid and many other organic compounds. Mucus of milkfish showed the presence of benzene, bromobenzene, benzaldehyde, acetophenone, uridine and furaldehyde. Mucus of mullet confirmed the presence of benzene, bromobenzene, acetylthiophene, guanosine, 2-picoline, cytidine,1- 3 butadiene andacetophenone. SEM analysis of scale showed the smooth structure of milkfish scale compared to seabass and mullet. Seabass scale have closely located tooth like rough surface whereas in mullet, ridges present were distantly located. Energy dispersive X-ray microanalysis (EDX) showed higher concentration of Ca, P, O, Na and C in milkfish

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scale when compared to seabass and mullet. Hence we conclude that the mucus of milk fish has significantly higher capacity to prevent ectoparasite infection.

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Studies on stress indicators in Indian spiny lobster *Panulirus homarus* (Linnaeus, 1758) under varying ammonia-N concentrations with special reference to Hsp70 and THP

Vidya, K., Shoji Joseph*, P. U. Zacharia and P. B. Ajithkumar
Central Marine Fisheries Research Institute, Kochi 682 018, Kerala, India. Email:sjvben@yahoo.com

Indian spiny lobster *Panulirus homarus* is a commercially important crustacean in most of the Asian countries and has been getting more and more interest in the aquaculture. Clear understanding of the physiological responses of spiny lobsters to environmental conditions is essential for the understanding of wild populations, their successful propagation, domestication as well as culture. The present study was undertaken to investigate the importance of environmental stress indicators, Hsp70 and THP in Indian spiny lobster P. homarus through molecular studies with respect to variations in ammonia-N concentrations. For ammonia stress, three different ammonia levels 3 mg/l, 1.5 mg/l and 0.5 mg/l were used, sampling was done on 1st, 7th and 15th day. Protein samples were separated using SDS PAGE; western blotting was done using Monoclonal Anti-heat shock Protein 70 (antibody produced in mouse) (Sigma) as primary antibody and Goat Anti-mouse IgG (HL), Horse Radish Peroxidase conjugate (Invitrogen) as secondary antibody. Chromogen used for the immune-detection was DAB System (Merck, Bangalore). For Hsp70 quantification direct ELISA method was adopted using the same antibodies. Standard graph was plotted and the Hsp70 concentrations of the samples were analyzed from the graph. Total protein estimation was carried out by Biuret method. Statistical analysis was carried out using SPSS software. One way Anova and GLM Uni-variate analysis of Variance were used.

Haemolymph samples of lobsters reared at four different ammonia concentrations (3 mg/l, 1.5 mg/l, 0.5 mg/l and 0.1 mg/l) showed brown bands in western blots which indicated the presence of Hsp70 protein. Hsp70 concentrations (F=306.970, df=3, p=< 0.01) were significantly different at different concentrations. Day wise studies also indicated significant difference in the three treatments of 0.5 mg/l, 1.5 mg/l and 3 mg/l compared to the control. The total haemolymph protein values of the lobsters exposed to 0.5 mg/l, 1.5 mg/l and 3 mg/l were observed to be significantly (p<0.1) lower than that of the control. More over, highly significant decrease in total haemolymph proteins was observed for 7th day and 15th day samples of 3 mg/l of ammonia treatment than the 1.5 mg/l treatment. The elevated levels of Hsp70 in higher concentrations of ammonia indicated that it was lethal to lobsters. The decreased haemolymph protein levels might be due

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to regulation of the metabolic activities of the lobsters during the time of stress. The data obtained would be useful in further refinement of lobster aquaculture in cages by improving the culture conditions thereby aiming at higher production.

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Effect of inactive marine actinomycetes on *Curvularia lunata* conidial germination, feather degradation and seed germination

Ganesan, T, K. Arunraj*, M. Priya, A. Antoniraj and G. Narchonai
Department of Botany, Tagore Arts College, Pondicherry 605 008, India.
Email: arunraj9566455714@ymail.com

Actinobacteria are known for their ability to produce a wide range of bioactive secondary metabolites having great structural and functional diversity. The terrestrial forms have been widely exploited and reported to produce hundreds of antibiotics and other bioactive molecules. However, the aquatic forms, particularly their estuarine and the marine counterparts, have been largely ignored and remain under exploited for useful metabolites. The increasing reports on new genus and species from the marine environment supports the view that marine ecosystem is not only unique but under-explored. In many screening programs only a fraction of isolates are reported active and the remaining majority are designated as inactive and left uncared or often discarded without testing for any other type of useful activity. Therefore in the present investigation we made an attempt to test the so called 'inactive isolates' for other bioactivities such as anticonidial germination activity, phytotoxicity and keratinolytic activity.

Fifteen 'inactive isolates' with different morphologies were selected for this study. The selected 'inactive marine actinomycetes' were grown in 25ml liquid medium in 100 ml conical flasks for 15 days as static culture at $30°\pm2°C$. The isolates were grown in five different media- Potato dextrose broth, ISP 2, starch casein broth, nutrient broth, soybean meal broth, pH 7.2-7.5. Culture filtrate was centrifuged at 5000 rpm for 10 minutes after 15 days. The clear supernatant was used without dilution for conidial germination studies using *Curvularia lunata* as the target organism. Species of Curvularia are now recognized not only as plant pathogens, but also as human pathogens as well. Conidial germination assay was conducted using cavity slide technique. Each cavity received $10\mu l$ conidial suspension followed by 100 μl culture filtrate, mixed well with sterile needle and incubated in humid chamber in dark. After 24 hours incubation the slides were examined under microscope and the percent inhibition was calculated. In a second set of experiment all the isolates were inoculated in boiling tubes containing 50-60 mg whole feather sterilized along with 20 ml mineral medium and incubated for 30 days under laboratory conditions. The tubes were agitated gently once every day. The tubes were visually evaluated for the disappearance of the feather. In the third set of experiment, effect of the culture filtrates (25 %) on green gram seed germination was tested in petriplates.

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Out of the fifteen isolates tested for anticonidial germination activity eight isolates produced no inhibitory effect in any of the five media tested. Five isolates evinced weak activity while two isolates showed strong activity and completely inhibited conidial germination. Among the two isolates with strong activity it was observed that the isolate M67 produced strong activity in PDB and ISP2 and weak activity in SCA and no activity in other two media. Further it was observed that the intensity of activity was higher in ISP2 than in PDB. The other isolate M86 produced strong activity in Nutrient broth and weak activity in ISP2 and SB. This indicates that the media composition plays a role in induction of specific metabolic pathway leading to production of the antifungal activity. Feather degradation studies showed that two isolates could completely degrade the chicken feather within 20 days. Isolate M67 only exhibited both antifungal and keratinolytic activity. The 3rd set of experiments on phytotoxicity showed that none of the isolates had any adverse effect on green gram seed germination. This second screening could recover two more isolates with useful activity from the so called 'inactive isolates' of the previous screening. The isolate M67 with strong activity could not be identified to species level though it shows resemblance to *Streptomyces phaeochromogens*. The biochemical characteristics and the smooth walled spores in long chains indicate that M67 is a member of the genus *Streptomyces*. The isolate M67 though did not affect mycelial growth (previous screen) but it strongly inhibited conidial germination and also exhibited keratinolytic activity. From this study it is clear that diverse screening programs should be included to test for variety of bioactivities under different physico-chemical conditions so that diverse activities can be recognized in each of the isolates which were earlier designated as 'inactive isolate'.

MECOS 2 |MBTP 15

Cytotoxic activity of marine sponges from southwest and southeast coasts of India

Deepa S. Rajan* and K. Padmakumar
Dept of Aquatic Biology and Fisheries, University of Kerala, Kariavattom, Thiruvananthapuram 695 581, Kerala, India. Email: deepa.anand.tvpm@gmail.com

Marine sponges were collected from intertidal and subtidal regions of south west and south east coasts of India. The alcoholic extracts of sponges were evaluated for cytotoxic activity using the Brine Shrimp (*Artemia salina*) Lethality Assay. From among 62 species of sponges assayed for cytotoxicity, 19 species were most toxic resulting in 100 % mortality. Sixteen species exhibited significant toxicity with more than 90 % mortality. Twenty species exhibited toxicity in the range of 80 % - 100 %. Ten species showed moderate toxicity with mortalities ranging between 50 % and 80 %. Sponges exhibiting remarkable activity include *Aulosponges tubulatus, Axinella agariciformis, Axinella donnani, Callyspongia spinosissima, Clathria procera, Clathria reinwardti, Dendrilla nigra, Echynodictyon gorgonoides, Petrosia similis, Fasciospongia cavernosa, Hymedesmia* sp., *Lotrochota baculifera, Ircinia compana, Orina sagittaria, Petrosia nigricans, Petrosia similis, Prostylyssa foetida,*

Psammaplysilla purpurea, Raspilia anstomosa, Stylissa carteri and *Zygomycale angulosa.*

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Influence of different culture media on the growth of marine actinomycetes and effect of the culture filtrates on conidial germination of *Curvularia lunata*

Narchonai, G.*, K . Arunraj, T. Janaki, A . Antoniraj, M. Priya, and T . Ganesan
Department of Microbiology, Bharathidasan University, Tiruchirappalli, Tamil Nadu, India.
Email: nesan14@yahoo.com

Bacteria belonging to the family Actinomycetaceae are well known for their ability to produce secondary metabolites, many of which are active against pathogenic microorganisms. Traditionally, these bacteria have been isolated from terrestrial sources. Marine actinomycetes have been reported to produce functionally unique metabolites and enzymes with unusual structures and properties that are not found in their terrestrial counterparts. This is due to their extreme living conditions within the marine environment. During the past decade, several workers have isolated actinomycetes from marine sediments and mangrove soil and screened for antifungal and antibacterial activity. But studies on effect of the antifungal metabolites of marine actinomycetes on fungal spore germination are limited. Therefore, in this investigation an attempt was made to test the effect of culture media of different composition on growth and production of antifungal metabolites by marine actinomycetes.

Thirty six isolates of marine actinomycetes with different colony morphologies were selected from the collection of previous screening program were used in this study. The selected isolates were serially numbered and grown in boiling tubes containing 20 ml each of three different liquid media (pH 7.2) - starch casein broth, yeast extract malt extract broth (ISP- 2) and soyabean-yeast extract broth. After 15 days of growth (still culture) the contents were centrifuged and the clear supernatants were used for conidial germination of *Curvularia lunata* using cavity slide technique. After 20 h incubation in humid chamber, the slides were observed under microscope and the percent germination/inhibition was recorded. Thirty six isolates were fermented in three different media for the production of antifungal metabolites. Six isolates (16.7 %) (isolates 4, 12, 20, 27, 31 and 32) did not produce active broth in any of the three media tested. The remaining 30 isolates (83.3 %) produced antifungal metabolites in one or more media. Only four isolates (isolates 19, 21, 23 and 35) produced antifungal metabolites in all the three media tested. Six isolates produced activity in two media. Fourteen isolates (46.7 %) produced activity only in one medium only. This indicates that about 47 % of the isolates need specific nutritional requirements to synthesize the antifungal compound. One of the most important parameters to assess the suitability of a culture medium is the product yield/intensity of activity. As the product yield/or activity is dependent on the metabolic pathways involved in the conversion of substrate

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into product, different values are to be expected when different media are used. Overall, 15 isolates completely inhibited conidial germination independently in ISP and SCB and only five isolates produced complete inhibition in soya-yeast extract broth. Further it was observed that nine isolates produced active broth in both in ISP and SCB; similarly five isolates produced activity in both SCB and soya-yeast extract broth. From the conidial germination studies it is concluded that soya-yeast extract broth is not a suitable medium to induce synthesis of secondary metabolites. Because soya medium supported vegetative growth and therefore no secondary metabolites were produced. On the other hand ISP and SCB, though former is organic and the latter, a synthetic medium, both supported growth and antibiotic production. The results indicated that nature and concentration of some components in fermentation medium have marked effects on antibiotic production. The production of secondary metabolites in actinomycetes is greatly influenced by various fermentation parameters such as available nutrients, pH, partial pressure of oxygen, temperature, agitation, mineral salts, metal ions, precursors, inducers and inhibitors, which often vary from organism to organism.

MECOS 2 |MBTP 17

In vitro mantle tissue culture of the winged pearl oyster *Pteria* sp.

Suja, C. P.
Central Marine Fisheries Research Institute, Tuticorin Research Centre, South Beach Road, Tuticorin 628 001, Tamil Nadu, India. Email: cpsuja@gmail.com

Pteria is a pearl producing mollusc in the family Pteriidae. The nacre layer in *Pteria* shows a distinct iridescence. Cultured pearl production in this genus is difficult due to its shape and thin shell structure. This study aims to unravel the possibility of *In vitro* nacre formation with the mantle tissue of the winged pearl oyster, *Pteria* sp. The animal with a shell length of 7.5 cm and width 4.2 cm was collected from the Punnakayal landing centre of Gulf of Mannar, as an incidental by-catch in trawl fisheries in 2006. Animals were thoroughly cleaned and brought to the tissue culture laboratory of Tuticorin research centre. Mantle tissue was excised from the animal and was given thorough cleaning in sterile sea water. The mantle strips were then treated in antibiotic solution of 1000 μg/ml streptomycin and 2000 IU/ml of penicillin. Again the strips were washed in sterile sea water twice and cut into small pieces of 2mm^2 size explants. Explant and organ cultures were organized. Medium 199 with 25 % supplementary salt solution and 10 % FCS was used for the cultures. Good number of cells were observed after 24 hrs in the explant cultures. The cells were in the range of 3- 11 μm with an average size of 9 μm. The mantle explant was inoculated over a 2mm nucleus (shell bead). Organic matrix and pearl sac developed in organ cultures around the entire nucleus. Experiments were repeated in 2009, 2010 and 2011 and obtained similar results. This experiment provides basic knowledge in *In vitro* studies and proved that this pearl producing mollusc is also a potential animal for producing nacre in *In vitro* conditions.

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In vitro culture of mantle tissue from the black-lip pearl oyster, *Pinctada margaritifera*

Vidya Jayasankar*, V. Srinivasa Raghavan, C. P. Suja, Indira Divipala, M. Bareen Mohamed and K. K Vijayan

Central Marine Fisheries Research Institute, Madras Research Centre, Chennai 600 028, Tamil Nadu, India.
Email: vidyajay@hotmail.com

Cell culture conditions for mantle epithelial tissue differ among varieties of molluscs. The viability of a primary cell culture is significantly dependent on the culture medium. Different cell types have different growth requirements, which make it necessary to formulate the most appropriate medium for a particular cell type. The present work was undertaken in order to establish a suitable culture medium for tissue explants from the mantle of the black-lip pearl oyster, *Pinctada margaritifera*. *In vitro* culture experiments were carried out using three different culture media, namely Leibovitz L- 15, sterile sea water and a 1:1 combination of L- 15 and sterile sea water. Effect of adding supplements such as foetal calf serum (10 %) and yeast extract (75μl/ml) solutions, on growth and proliferation of mantle epithelial cells was also studied. All culture procedures were carried out under sterile conditions in a laminar airflow chamber.

Healthy *P. margaritifera* were depurated and kept overnight in seawater containing antibiotics penicillin-streptomycin and fungicide amphotericin B solutions (100 μl/ml), prior to being used for excision of mantle tissue. The surface of the animals was sterilized using 75 % alcohol, the valves of the animals were opened and mantle tissue was dissected using a sharp scalpel and transferred to a bowl containing sterile seawater. Strips of pallial region of the mantle tissue were excised, rinsed in sterile sea water, dipped in 35 % alcohol for 30 seconds followed by another rinse in sterile seawater, and treated in antibiotic solutions of penicillin and streptomycin (100 μl/ml) and amphotericin B (100 μl/ml) prepared in sterile seawater.

The mantle strips were finally cut into 2- 3 mm size pieces using a sharp blade and transferred to a petri dish containing sterile seawater. The explants were inoculated into sterile 12-well plates for *In vitro* culture experiments using different media and supplements. Three replicates were maintained for each treatment. The explants were left undisturbed for 10-15 min to ensure their attachment to the culture plate, following which 2 ml of the respective test medium was added per well in all the plates. Culture plates were covered, sealed with parafilm and incubated at 25° C. Development of cultures was monitored at regular intervals under an inverted microscope (Nikon) for 14 days. Cell cultures were assessed in terms of culture initiation, cell yield and susceptibility to contamination. Cell counts were made and cell size was measured for each treatment. Cells were observed to be released and migrated from the explants 24 hours after initiation of the cultures. The liberated cells were mostly round and were either granulocytes or hyalinocytes. Fibroblast-like cells were also observed in large numbers within 24 hours after initiation of cultures. The present study showed that among the culture media tested, sea

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water medium gave better results in terms of cell proliferation, followed by the 1:1 combination of L- 15 with sterile sea water and L- 15 medium (Fig. 1). Size of cells in sterile seawater medium was comparable with that obtained in L- 15 medium (Table 1). Supplementation of culture media with 10 % foetal calf serum and yeast extract improved both cell number and size.

The results of our study revealed the prospects of using sterile seawater with supplements as an alternative medium for mantle tissue culture, in place of expensive commercial media such as L- 15. Further studies are in progress to formulate a new cost-effective culture medium using sea water as a base.

Table. 1. Comparison of different media with regard to cell size in mantle explant culture of the black-lip pearl oyster, *Pinctada margaritifera*

S. No.	Medium	Cell Size (μm)
1.	Sterile seawater	9.27
2.	Sterile seawater with supplements	11.25
3.	L-15	13.39
4.	L-15 with supplements	14.94
5.	L-15 + sterile seawater (1:1)	7.62
6.	L-15 + Sterile seawater (1:1) with supplements	12.86

Fig. 1. *In vitro* cultures of *Pinctada margaritifera* mantle tissue: a. L-15 medium b. Sterile seawater medium c. L-15 with sterile sea water (1:1) medium

In vitro culture of embryonic stem (ES) cells from the marine ornamental false clown *Amphiprion ocellaris* Cuvier 1830

Sobhana, K. S.*, Sheethal Mary Sunny, Shuchi Agarwal, K. Madhu, Rema Madhu, C. Kalidas and M. Sakthivel
Central Marine Fisheries Research Institute, Kerala 682 018, Kerala, India.
Email: sobhanapradeep11@gmail.com

Embryonic stem (ES) cells provide unique tools for cell-mediated gene transfer and targeted gene mutations due to the possibility of *In vitro* selection of desired genotypes. Establishment of ES gene targeting techniques in cultured fish provides a novel approach for genetic improvements, developmental biology, and analysis of gene function in fish. Thus ES cell lines are urgently desired for use in basic and applied research. The present paper discusses *In vitro* culture of blastomeres isolated from mid-blastula stage embryos of the orange clown fish *A. ocellaris*. *In vitro* culture conditions for initiating primary culture of embryonic stem cells from *A. ocellaris* were optimized using tissue culture medium formulated with Leibovitz- 15, Dulbecco's Modified Eagle's Medium and Ham's F12 with various supplements and growth factors. Newly fertilized eggs of *A. ocellaris* attached to earthen pots (substratum) were collected from the marine hatchery of Central Marine Fisheries Research Institute, Kochi and maintained in the cell culture lab. The developmental stages were monitored by observing a sample of eggs under an inverted microscope at different time intervals. Enzymatic treatment and mechanical separation were attempted for isolating blastomeres from the embryos and the latter method gave better results with minimum interference of yolk globules. In order to standardise the optimum stage of the embryos for initiating primary stem cell culture, blastomeres were isolated at different stages viz., 16, 32, 64, 128 and 256 cell stage embryos and it was found that the mid blastula stage with 256 cell stage gave better blastomere attachment and multiplication. Different substrates were compared for efficacy of blastomere attachment. Blastomeres were seeded onto feeder fibroblasts (developed from *A. ocellaris*) as well as in feeder free culture dishes. For feeder free culture, polystyrene cell culture dishes (with and without coating) and glass dishes were compared. Among the different substrates used, feeder layer and glass dishes were found to have better blastomere attachment and multiplication.

Functional food products from marine bioactive compounds

**Kajal Chakraborty*, Deepu Joseph, Selsa J. Chakkalakal, Vamshi K. Raola and Pananghat Vijayagopal**
Central Marine Fisheries Research Institute, Kochi 682 018, Kerala, India. Email: kajal_cmfri@yahoo.com

Bioactive components and functional food ingredients from marine organisms demonstrated a myriad of benefits for human health and multiple life threatening diseases, and therefore, are attractive options for food and pharmaceutical industries. Bivalve mollusks and seaweeds are abundantly available in the coastal and oceanic ecosystem, and these *Candida*te organisms can potentially be used to isolate high value compounds for human health benefits. The research work in this direction led to the development of neutraceutical products Cadalmin™ Green Mussel extract (GMe) and Cadalmin™ Green Algal extract (GAe) with enriched bioactive principles for use against oxidative stress-induced inflammatory diseases. The active principles in Cadalmin™ GMe isolated from *Perna viridis* competitively inhibit inflammatory cycloxygenases (COXI,II) and lipoxygenase (LOXV) in an inflammation and oxidative stress reaction, resulting in decreased production of pro-inflammatory mediators. The active principles registered greater COXII and LOXV inhibition (70-75 %) than aspirin and indomethacin (55-66 %) at a comparable dose. *In vivo* animal model studies revealed that the active principles suppressed (64-77 %, 2-4h) the edema produced by histamine. Long term chronic toxicity studies did not produce any toxicity to these animals. Also it did not produce any biochemical changes related to the functions of the vital body organs.

An anti-arthritic and 100 % vegetarian nutraceutical Cadalmin™ GAe (Cadalmin™ Green Algal extract) has been developed from selected seaweeds. The product is effective in combating arthritic pain and inflammatory diseases in human beings. The efficiency of Cadalmin™ GAe to inhibit COXII and LOXV stands at 64-94 % as compared to 40-52 % for a popular painkiller that was also reported to induce adverse effects on various metabolic and physiological parameters in human beings. A lower COXI / LOXV and COXI/II (lesser than 1.0), dual inhibitory activity of COXII and LOXV, and significant *in vivo* activity indicate a better therapeutic profile and fewer side effects of CadalminTM GAe than the synthetic non-steroidal antiinflammatory drugs. Time dependent *In vivo* animal model studies on mammalian subjects revealed the inhibition of inflammatory response to the tune of 73-76 % by Cadalmin™ GAe and its active components as compared to a maximum of 70 % for the popular painkiller aspirin that was reported to induce adverse effects on various human metabolic and physiological parameters. The product has been proved to be safe during the acute and chronic toxicity studies on experimental subjects. The mean lethal dose (LD50) of Cadalmin™ GAe was found to be greater than 4000 mg/kg body weight of the mammalian subjects, indicating the safety of the product. Marine fishes are rich natural resources of long chain *n*-3 polyunsaturated fatty acids (PUFA), which are essential in the diet of human beings because of their inability to adequately synthesize them. PUFA derived from chemically hydrolyzed sardine oil was concentrated by pluralities of

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physicochemical procedures to afford eicosapentaenoic acid (C20:5n-3) with high purity (47.78 %). The PUFA enriched formulation from low value "fish body oils" will also answer the risks associated with hypervitaminosis associated with liver oils.

It is significant to note that the effect of the bioactive compounds in the functional food or nutraceutical products may be invisible towards the health parameters over relatively short periods. However, these ingredients contribute significantly to health when they are consumed throughout life as part of the daily diet. The increasing interest in marine-based functional food ingredients and nutraceutical formulations as evidenced by the scientific papers published in the last decade correlating diet and human health have shown the possibilities of bioactive compounds and nutritional elements from marine organisms to maintain and improve human health and well-being.
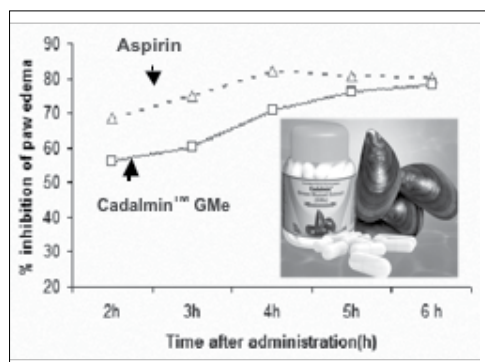
Efficacy of estuarine plant extracts against *Vibrio harveyi* during shrimp larviculture

Kannappan, S.*, K. Siva Kumar, M. Dinesh Kumar
Central Institute of Brackishwater Aquaculture, 75 Santhome High Road, Chennai 600 028, Tamil Nadu, India. Email: sudalikanna@gmail.com

The extracts were prepared from the estuarine plants such as *Sesuvium portula castrum, Exoecaria agallocha, Rhizophora apiculata* and *R. mucronata*. The crude extracts from *S. portulacastrum* showed 9.4± 0.2 mm inhibitory zone against *Vibrio harveyi* and *E. agallocha* (Thillai) showed 9.9± 0.4 mm. But *R. apiculata* and *R. mucronata* showed 7.1± 0.2 & 7.2± 0.2 mm against *V. harveyi*. When, *V. harveyi* grew in Luria Bertani (LB) broth with *S. portulacastrum* extract at 100µg/ ml, the growth was decreased from 0.40 to 0.27 OD in 5 days. In control, *V. harveyi* growth was increased from 0.46 to 1.11 OD. Similarly, *E. agallocha* extract reduced the growth from 2.946 to 1.782 OD in 5 days as compared to control (3.290 to 3.592 OD). The growth difference on *V. harveyi* was also much similar

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against Rhizophora extracts.

When, *S. portulacastrum* extract was treated against the virulence factors (phospholipase, luciferase, and bio-luminescence) produced by *V. harveyi*, these became weak. Crude bacteriocin values were reduced from 1.36 to 0.82 OD as compared to control (1.794 to 2.035 OD). Protease production was changed from 0.217 to 0.081. *E. agallocha* extract also showed weak virulence factors. The crude bacteriocin values were reduced from 1.937 to 1.452 OD as compared to control (2.073 to 1.739 OD). Exopolysaccharide produced by *V. harveyi* varied from 2.791 to 2.691OD as compared to control (3.387 to 3.23). *R. apiculata* extract against *V. harveyi* showed strongly hydrophobic nature and reduced 2108 CPS of luminescence as compared to control (88443 CPS), but *R. mucronata*, reduced only 1191 CPS. Both the extracts had reduced exopolysaccharides to 0.35 level as compared to control and the phospholipase activity was reduced moderately by the Rhizophora extracts.

Crude *S. portulacastrum* extract, when challenged against *V. harveyi* during *Penaeus monodon* larviculture, the cumulative percentage of mortality (CPM) of postlarvae increased in the control from 9.5 to 66.7 % in 30 days. The differences of reduction on cumulative percentage mortality in the treatment were 13 % as compared to the control. However, *E. agallocha* showed increased CPM in the control from 4 to 74.4 % for 5th to 30th days.The differences in the CPM in the treatment tank were 4 to 14 % respectively. The CPM reduction on PL was found to be 13 % treating against *R. apiculata* extract till 30 days. Whereas, *R. mucronata* showed 9 % cumulative percentage mortality reduction.The GC-MS profile of Ethyl acetate extract of *S. portulacastrum* showed various compounds such as 2 (3H)-Benzoxazolone (50.09 %), 2(4H)-Benzofuranone, 5,6,7,7a-tetra-hydro-4,4,7a-trimethyl (7.51 %), n-Hexadecanoic acid (7.18 %). *R. mucronata* was found to have 31 % of squalene and 38 % of Tetramethyl-6,7,8,8a-tetra-hydro-5H-naphthalen-1-one compounds whereas *R. apiculata* was reported to have 61 % of squalene. The *E. agallocha* extract was found to have compounds such as Phytol acetate, hexadecanic acid, squalene, Octa and Nonodecane and Alpha amyrin etc. These results proved that various bio-active compounds present in the plant extracts may be antagonistic against *V. harveyi*. The crude extracts may be used as non-antibiotic bio-potential proxy to control bio-luminescence disease causing *V. harveyi* in shrimp larviculture system.

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Screening of seaweeds from Pulicat Lake for biofuel

Sasi, M. C. and Lita Sunder*
Department of Marine Studies & Coastal Resource Management, Madras Christian College, Chennai 600 059, Tamil Nadu, India. Email: lita_sunder@yahoo.co.in

The drift seaweeds *Enteromorpha compressa, Chaetomorpha linum, Gracilaria edulis* and *Gracilaria verrucosa* occurring in large quantities along the shores of Pulicat Lake were considered for their bioavailability as biofuels. They were

analyzed for the composition of fatty acids. The seaweed *Gracilaria edulis* and *Gracilaria verrucosa* have high percentage of palmitic acid i.e. 84.60 % and 81.28 % respectively, whereas they were not detected in *E. compressa* and *C. linum*. This shows that *G. edulis* and *G. verrucosa* with high amount of fatty acids have the potential for the production of biodiesel.

The conclusions of this study are that *G. edulis* and *G. verrucosa* occurring as drift weeds can be utilized for the production of biofuels. Further studies on optimal enhancement of fatty acid extraction employing bioengineered organisms would help to utilize this unutilized resource. It would serve as an alternate income for the fishermen community of Pulicat Lake. Later, with increasing demand, suitable technologies can be developed for culturing these seaweeds which can also serve as an alternate source of livelihood for fishermen.

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MECOS 2 |MBTP 23

Enhanced level and prolonged duration of induced thermal tolerance and relative mRNA expression of stress management genes in the Indian edible oyster *Crassostrea madrasensis* (Preston)

Paulton, M. P.*, P. C. Thomas and A. Gopalakrishnan
Central Marine Fisheries Research Institute, Kochi 682 018, Kerala, India. Email: meleth_paulton@yahoo.co.in

Temperature tolerance of a species is an indicator which determines its potential to persist or become extinct in response to climate change and related environmental challenges. Identifying the winner species which can withstand the increasing biotic and abiotic challenges is essential for sustainable culture practices, and thereby to ensure food for future. Bivalves living in aquatic environment, especially in inter tidal region, are more prone to a variety of challenges and possess high level of tolerance to these stressors. Aquaculture of the Indian edible oyster (*Crassostrea madrasensis*) is becoming more popular along the Indian coasts. Hence, knowledge on the thermo tolerance limits, the molecular mechanisms behind stress tolerance, and enhancement of thermo tolerance through induction shall be of immense use for the scientific management of the system to ensure sustainable production.

The oysters with size ranging from 70-80 mm collected from an oyster farm located in Sathar Island near to Vypeen Island, Kochi were cleaned well and acclimated in aerated sea water of salinity 22 ppt. The water temperature was maintained at 28°C to 30°C and the oysters were fed with micro algae *Nannochloropsis* and *Isochrysis*. The maximum temperature at which the oysters show tolerance and survive without mortality and the temperature at which almost all (nearly hundred percent) animals succumbed to death are referred to as sub lethal temperature (SLT) and lethal temperature (LT) respectively. SLT and LT were determined as 44°C and 47°C respectively by exposing the acclimated oysters to temperatures ranging

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from 37˚C to 47˚C for one hour and monitoring the survival in normal acclimation temperature (28˚ C) for one week. Gills of oysters recovering from SLT as well as from control animals were collected at regular intervals (0hr, 6hr, 24hr and 48hr) and stored in RNA later (Sigma) to study the relative expression of stress and defence management genes. Transcriptomic analysis using the cDNA transcribed from the RNA extracted have shown a statistically significant up regulation of the mRNA of heat shock protein 70 (Hsp70) and super oxide dismutase (Cu/Zn SOD) in oysters recovering from SLT. In order to study the impact of salinity on thermal limits, oysters acclimated in hyper (35 ppt) and hypo (3 ppt) saline sea water for ten days were subjected to SLT (44˚C) for one hour and allowed to recover at 28˚ C. As hypothesized, while the oysters maintained at 22 ppt and 35 ppt have shown absolute survival, eighty percentage of oysters maintained at hypo salinity (3ppt) succumbed to death within two days of recovery. The oysters recovering from SLT at 44˚C were further exposed to lethal shock (47˚C) on 2nd day, 7th day, 14th day and 26th day to study induced enhancement in thermo tolerance.

The oysters which had received sub lethal shock (SLT) at 44˚C were found to be resistant to the subsequent lethal temperature (LT) shock (47˚C), while the control animals not exposed to SLT succumbed to death. The phenomenon of induced tolerance was evident. Retention of the induced tolerance up to 26 days after recovery from SLT noticed in the study is a record duration reported in any animal. Thus, the general up regulation of stress and defence management genes noticed in oysters recovering from SLT have been contributing to the phenomenon of induced, enhanced tolerance as noticed in this study. As reported earlier, the oysters surviving high temperatures could also survive other biotic stressors like parasites and microbial attack through the phenomenon of cross tolerance. The study has revealed the special potential of Indian edible oyster (*C. madrasensis*) in thermo tolerance and induced enhanced thermo tolerance over its European and western counter parts such as *C. gigas* and *C. virginica*. Thus, the Indian edible oyster (*C. madrasensis*) could be projected as a winner species with the ability to survive the challenges posed by climate change and related issues.

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MECOS 2 |MBTP 24

Purification and characterization of antimicrobial peptides from the cuttlefish *Sepia pharaonis*

Ajitha, T. V., K. S. Sruthy*, Naveen Sathyan, E. R. Chaithanya, P. R. Anil Kumar and Rosamma Philip
Dept. of Marine Biology, Microbiology and Biochemistry, School of Marine Sciences, Cochin University of Science and Technology, Kochi 682 016, Kerala, India. Email: sruthyks50@gmail.com

Antimicrobial peptides (AMPs) are evolutionarily conserved innate defence effector molecules which exhibit enormous distribution throughout the kingdom of life from bacteria to plants and animals. AMPs are gene-encoded, ribosomesynthesized peptides having a molecular mass less than 10 kDa, a net positive charge of +2 to +9 and a membrane active amphipathic nature. These peptides possess multi-

faceted biological activities including anti-bacterial, anti-fungal, antiparasitic, anti-biofilm, anti-viral, anti-tumor and immunomodulatory activities. The potential of AMPs to overcome bacterial resistance mechanisms and its high therapeutic index marks them as promising contenders for therapeutic drugs. Survival of aquatic organisms, mainly invertebrates in a microbe laden aquatic milieu, is reinforced by AMP-based innate immune defence system. Present study deals with the isolation and characterization of antimicrobial peptides from the cuttle fish *Sepia pharaonis*.

Experimental organism, *S. pharaonis* was collected during the cruise no. 292 of FORV SAGAR SAMPADA (Ministry of Earth Sciences, Govt. of India). For the screening of novel AMPs by analytical approach, the crude protein was extracted according to the protocol described by Rivillas and Soreano (2007) with slight modifications. Whole body except the cuttle bone and digestive tract were homogenized with 10 % acetic acid in the ratio 1:5 (W: V) and centrifuged at 13,500 rpm at 4˚C for 20 minutes. Crude protein was precipitated using ice cold acetone, centrifuged and crude pellet was stored at - 20˚C. Crude peptide was screened for antimicrobial activity against selected bacterial and fungal strains i.e., *Bacillus cereus, Edwardsiella tarda, Staphylococcus aureus, Aeromonas hydrophila, Vibrio proteolyticus, Vibrio fluvialis, Pseudomonas aeruginosa, Fusarium solani* and *Candida tropicalis* (Fig.1 and 2) by disc diffusion as per Bauer *et al.* 1966. The highest activity was recorded against *E. tarda.* Partial purification of Crude protein extract reconstituted in 0.1 % tri fluoro acetic acid (TFA) was carried out in Sep-Pak, Vac- 12 cartridges (Waters). The analyte trapped in the cartridges were eluted and fractions were labelled as 5 %, 40 % and 80 % and stored in -80˚C until use. Further purification of lyophilized 40 % Sep-Pak. was carried out by cation exchange column chromatography using FPLC (Fast Protein Liquid Chromatography) system (BioRad-BioLogic Duo flow) with column UNOTM QI (QI BioRad) (Fig.3). Each peak was collected as separate fractions, which were lyophilized and stored at -20° C until use.

Purified fractions obtained were named as Sp40- 1, Sp40- 2, Sp40- 3 and Sp40-4 and examined for antimicrobial activity by disc diffusion assay (Fig.4). FPLC
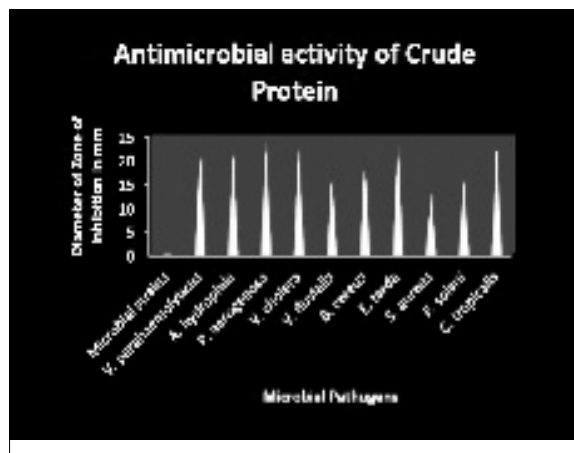

Fig. 1. Disc diffusion assay of crude protein sample

Fig.2 Antimicrobial disc diffusion assay

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fraction Sp40-4 showed maximum antibacterial activity against gram positive bacteria, *B. cereus* (12 mm) and *S. aureus* (10 mm) and gram negative srains like *V. fluvialis* (9 mm), *A. hydrophila* (10 mm), *E.tarda* (14 mm). Each fractions Fig. 1. Disc diffusion assay of crude protein sample Fig.2 Antimicrobial disc diffusion assay were subjected to protein quantification by absorbance assay at 230 nm (Stoscheck, C. M., 1990) and found to be 2.4 mg/ml, 1.3 mg/ml, 0.9 mg/ml and
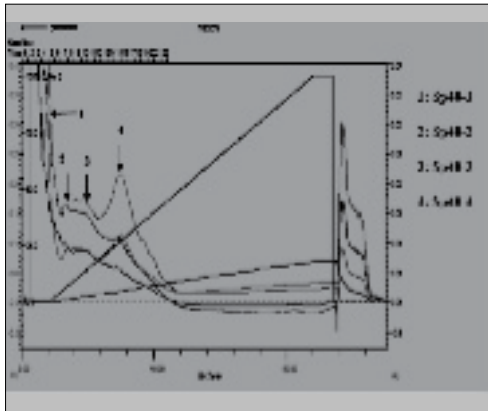
Fig.3 FPLC profile of crude peptide extract of *S. pharaonis*
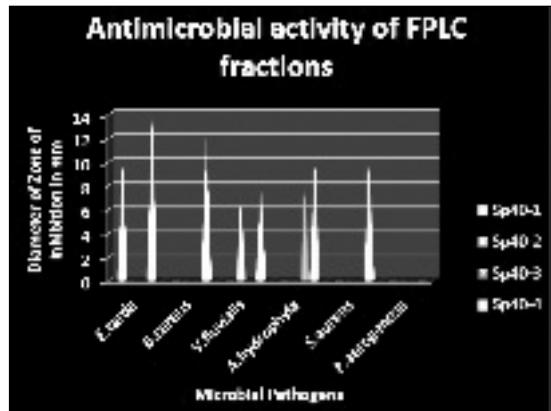
Fig. 4 Disc diffusion assay of FPLC fractions.

19.6 mg/ml respectively for Sp40- 1, Sp40- 2, Sp40- 3 and Sp40-4. SDS-PAGE was performed to determine the molecular weight and number of peptides in each fraction. Molecular weght was determined by comparison with the protein marker and found to be 3 kDa, 25 kDa, 14 kDa and 30 kDa for Sp40- 1, Sp40- 2, Sp40- 3 and Sp40-4. Fig.3 FPLC profile of crude peptide extract of *S. pharaonis* Fig. 4 Disc diffusion assay of FPLC fractions. Amino acid sequencing and structural characterization of the peptides are to be done. It can be concluded from the results that *S. pharaonis* is a potent source of antimicrobial peptides with high potential for prophylactic and therapeutic applications.

MECOS 2 | MBTP 25

Antimicrobial activity of Actinomycetes isolated from Sankarabarani River estuary, Puducherry

Priya, M.*, B. Anandaraj, K. Arunraj and T. Ganesan
Department of Microbiology, Indira Gandhi College of Arts and Science, Pondicherry 605 009, India.
Email: abiram1978@gmail.com

The marine environment is appreciated as an exceptional reservoir of bioactive natural compounds which exhibit diverse structural and chemical features which are not found in terrestrial natural products. Actinomycetes are Gram +ve bacteria rich in G+C content in their DNA and are well known for their ability to produce

diverse bioactive compounds. Genus *Streptomyces* produces more than 60 % of the known antibiotics. The present study was aimed to isolate actinomycetes from Sankarabarani river, Puducherry and to determine the antimicrobial potential of isolated actinomycetes against pathogenic fungi and bacteria as very few reports are available pertaining to estuarine actinomycetes.

Soil sample was collected (15 cm depth) from the Sankarabarani river estuary near boat house – Ariyankuppam, Puducherry. The sample (500 g) was transferred to sterile polythene bag, brought to the laboratory and dried in an oven at 40˚C for seven days to reduce bacterial contamination. The soil sample was gently crushed using a sterile mortar and pestle, sieved (2mm mesh) and stored. Two soil pretreatments were used to enhance the chances of isolation of rare actinomycetes. The pretreatments were SDS-yeast extract and phenol (1.5 %) treatments. The soil sample (10 g) was serially diluted in sterile physiological saline (0.8 %) and the 4th dilution was used for inoculation. One milliliter of the final dilution was aseptically transferred to sterile pertiplates followed by 20 ml sterile molten (40˚C) medium and swirled gently to mix the medium and the aqueous sample. Three different media - Starch casein agar (SCA), Humic-acid vitamin agar (HVA) and Water agar (WA) prepared with 30 % sea water were used for isolation. All the media were amended with nalidixic acid and cycloheximide (50μg/ml) to control bacterial and fungal contaminations respectively.

The inoculated plates were incubated under laboratory conditions (30°±2°C) for 30-60 days. The suspected colonies were sub cultured on PDA with 30 % sea water and the colony purity was rechecked by repeated streaking on PDA and then used for screening. Morphologically different 23 actinomycete isolates were selected for screening and were grown in potato dextrose broth with 30 % sea water for 15 days. The culture filtrate was centrifuged at 5000 rpm for 10 minutes and the supernatant was used for bioassay. Nutrient agar plates were swabbed with 24hrs old bacterial cultures (Staphylococcus aureus, *Pseudomonas aeruginosa*, *Bacillus subtilis*, *Proteus vulgaris*, and yeast *Candida* albicans) using sterile cotton swabs. Wells (6mm diameter) were punched with the help of sterile cork borer on agar plates. The wells were filled with 50 μl culture filtrate and incubated under laboratory conditions for 24- 30hrs. The inhibition zones were recorded after 24-30 hrs. For *Curvularia lunata*, 6mm dia. fungal discs punched from an actively growing fungal colony were used to inoculate the test plates. Suitable control was run along with the experiment.

Out of 23 isolates, seven isolates (30.4 %) exhibited antimicrobial activity towards one or more test organisms. Antibacterial activity was more frequent than antifungal activity. Five isolates exhibited antibacterial activity, three isolates exhibited anticurvularia activity and only one isolate evinced anti-*Candida* activity. Further it was noticed that Gram negative bacteria were inhibited by more number of isolates (n=5), than gram positive bacteria (n=3). Within the gram positive forms *B. subtilis* was more sensitive than *S. aureus*, similarly *P. aeruginosa* of Gram negative form was more sensitive than *P. vulgaris*. None of the isolates inhibited growth of *P. vulgaris*. The filamentous fungus *Curvularia lunata* was only moderately sensitive to three (13 %) of the estuarine actinomycetes. Only one isolate PS-9 showed broad spectrum antagonistic activity and therefore selected for further study. The isolate was identified as member of the Genus *Streptomyces* based on biochemical and physiological characteristics and spore chain morphology.

From this study it is concluded that secondary metabolites from estuarine actinomycetes shows strong inhibitory activity especially towards Gram negative bacteria indicates their selective target specificity. This is may be due to the presence of some special structural and chemical features in estuarine secondary metabolites (antibiotics) which is not present in terrestrial forms. Therefore this habitat deserves further detailed study.

MECOS 2 |MBTP 26

Spongosorites halichondriodes as a potential source of bioactive compounds

Maushmi, S. Kumar* and Asim, K. Pal
Shobhaben Pratapbhai Patel School of Pharmacy and Technology Management; SVKM'S NMIMS, Mumbai 400 056, Maharashtra, India. Email: maushmiskumar@gmail.com

Demospongiae is known to produce the most diversified secondary metabolites isolated till recent years. However, the bioactive compounds from Indian sponges have not been studied extensively and very few works have been cited in the literature. Based on the knowledge on terrestrial biodiversity, it is believed that the greatest biodiversity of organisms are from tropical and sub-tropical water regions. About one third of the discovered marine compounds have been isolated from sponges and their symbiotic microorganisms. Marine sponges are the most primitive multicellular animals containing metabolites not found in their terrestrial counterpart, in particular glycolipids having unusual long chain fatty acids (FA) sometimes with a third double bond or a bromine atom (Litchfield and Morales, 1976). Sponges maintain structural features in their cell membranes which contain sterols, phospholipids and thus exhibit sterol-phospholipid interactions which play a major role in cell membranes (Barnathan and Kornprobst, 1998). Phospholipids like methylene-interrupted poly unsaturated fatty acids (PUFA) and very long chain acids known as demospongic acids have also been reported in sponges. Marine invertebrates are filter feeders and consequently harbor many symbiotic microorganisms. Thus, for such organisms, a particular fatty acid appears as biomarker. Seven monoindole derivatives have been isolated from the methanol extract of marine sponge *Spongosorites* sp. by bioactivity-guided fractionation. Five compounds were identified to be unique indole pyruvic acid derivatives (Bao *et al.*, 2007). Bis (indole) alkaloids of topsentin class and hamacanthin class obtained from the same sponge have been investigated for their biological property. Compounds of the hamacanthin class have been found to exhibit more potent antibacterial activity than those of the topsentin class against various strains of bacteria and fungi (Oh *et al.*, 2006). These Bis indole alkaloid have also displayed fibronectin-binding property which highlights the potential of these compounds for the treatment of *Staphylococcus aureus* infections via inhibition of sortase activity (Oh *et al.*, 2005).

In continuation of our search for drug leads from the Arabian Sea sponge *Spongosorites halichondriodes*, we have characterized and isolated several

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bioactive compounds from the ethyl acetate and butanol extract fractions. Ethyl acetate fraction demonstrated cytotoxicity on MDA-MB-435 human breast cancer cell line with GI50 of 19.7 μg/ml. Bioassay-directed fractionation of the active extracts resulted in the identification of two new glycosylated steryl derivatives and two known 2,2,6,6-tetramethyl-4-piperidone and pyrrole compounds which were isolated and tested for antimicrobial activity and cytotoxicity. The glycosylated steryl compounds and piperidone exhibited positive antimicrobial activities without any cytotoxic property. The present study is focused on the isolation and biological evaluation of metabolites from the marine sponge *S. halichondriodes* for their antibacterial, antifungal and cytotoxic activities. Identification of bioactive compounds has been based on the bioassay guided fractionation and isolation. Three alkaloids (1,2,3) and two steryl glycoside derivatives A-B (4,5) have been isolated by chromatographic fractionation and purification of the bioactive ethyl acetate and butanol fraction. The structures were determined by the UV, IR, 1D NMR and high-resolution mass spectral studies like GC-MS/MS and LC-MS/MS. In addition to these, other compounds like methyl and ethyl benzoate, decanoic acid, 2,5-dichloroaniline, *N*-Nitroso dicyclohexylamine, 7-methoxy-6-methylcoumarin were also isolated and identified using GC-MS/MS (Kumar & Pal, 2013).
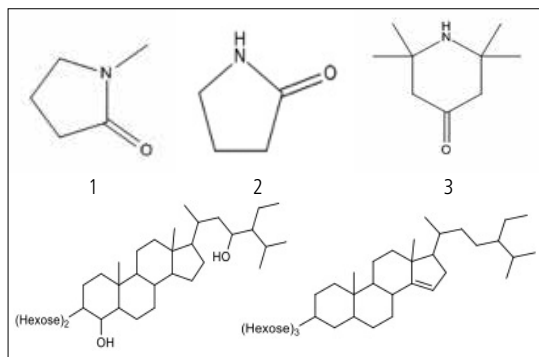
Fig.1. Structures of compounds isolated from the marine sponge *Spongosorites halichondriodes*

Method of isolation and characterization of fucoidan from the brown seaweed *Sargassum wightii*

Rajendran, I.*, P. Vijayagopal and K. K. Vijayan
Central Marine Fisheries Research Institute, Mandapam Regional Centre, Mandapam Camp, Ramanathapuram 623 520, Tamil Nadu, India. Email:cmfrirajendran@gmail.com

Gulf of Mannar (GOM) is having rich sources of seaweeds. Brown seaweeds are the source of valuable products which are useful as medicinal products, in mariculture and also in agriculture. They include sulphated polysaccharides (SPS) of anionic nature and neutral type besides minor fatty acids, sterols, pigments, lipids, proteins, fibre, etc. These products are having varied applications.

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Sargassum wightii [*Anthophycus wightii*] is one of the major brown seaweeds of Mandapam coast of GOM and the main source of algin. Besides algin, fucoidan, the hydrophilic fraction of this brown seaweed is one of the SPS having fucose units. It is an important product and highly valued for its medicinal properties with wide spectrum of biological activities. A methodology has been standardised for the isolation of fucoidan. The crude fucoidan has been isolated, purified and characterized by HNMR. Various applications of fucoidan have been discussed.

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Evaluation of bioactive compounds from marine Actinomycetes against clinical pathogens

Prasad, M. P.
Department of Microbiology/Biotechnology, Sangenomics Research Lab, Bangalore 560 071, Karnataka, India. Email: drprasadmp@gmail.com

The aim of the present investigation was to isolate antibiotic producing Actinomycetes. Actinomycetes, especially members of the genus *Streptomyces*, are responsible for producing the majority of known antibiotics. The Actinomycetes strains were isolated from marine sediment samples collected from the coastal areas of Mangalore, Mandapam and Trivandrum in India by serially diluting the samples and plating them on Actinomycetes isolation agar, ISP^{-2} agar and Starch Casein agar prepared in sea water and incubated at 25°C for 3-5 days. Actinomycetes were identified based on the morphological and biochemical characterization.

A total of 15 strains were isolated out of which only 4 showed antibacterial activity against 8 selected human pathogens like *Escherichia coli*, *Staphyloccus aureus*, *Streptococcus pyogenes, Salmonella* sp, *Klebsiella* sp, *Serratia* sp, *Bacillus* sp, *Pseudomonas aeruginosa* isolated from clinical specimens. Further optimizations of different media conditions, both physical and chemical (Carbon, Nitrogen sources, pH and temperature) was conducted by growing the *Actinomycetes* with varying components in the media and plating the supernatant on to Mullher Hinton agar by well diffusion method. The growth and yield of secondary metabolites was maximum with the use of ISP^{-2} agar, pH 7, incubation temperature of 25°C and incubation time of 48-72 hours. Maltose as the source of carbon showed good activity and Ammonium nitrate as source of nitrogen against most of the test pathogens used. All the four Actinomycetes isolated showed activity against both gram positive and Gram negative micro organisms used in the present study. *E.coli*, *Serratia* sp. and *S. aureus* were the most sensitive amongst all the pathogens, Salmonella sp. also showed sensitivity to a certain extent. Amyl alcohol extraction showed the maximum activity against all the pathogens. The minimum inhibitory concentration for which the organism showed antimicrobial activity was found to be 20 μL. The study indicates the potential of the Actinomycetes strains which can be a source for commercial production. Further studies like use of Inducers and Strain improvements can lead to production at industrial scale.

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Isolation and screening of marine Actinomycetes for anti-proliferative activity

Dhaneesha, M * and T. P. Sajeevan
National Centre for Aquatic Animal Health, Cochin University of Science and Technology, Lake Side Campus, Kochi 682 016, Kerala, India. Email: dhaneeshamdas@gmail.com

The rich biological diversity of marine environment offers enormous scope for discovery of novel bioactive compounds and several of these can act as potential leads for biomedical development. Marine actinomycetes are promising *Candida*tes for drug discovery since they have developed unique physiological and metabolic capabilities to adapt to extreme marine habitats which will make them capable of producing potential bioactive compounds with pharmacological activities. In the present study marine Actinomycetes strains isolated in pure culture from marine sediment samples collected along the south west coast of India were tested for their anticancer activity on cell line. The culture extracts of the isolates were prepared by extracting the broth and mycelia with ethyl acetate and acetone respectively. The extracts were further concentrated and the residue was re-dissolved in 0.1 % DMSO. The crude extract of the isolates were assessed for anti -proliferative activity on NCIH460 small lung cancer cell line by using Sulforhodamine assay (SRB). In the screening isolate DML 30 showed promising anti-proliferative activity in culture broth as well in mycelia extract and two other isolates viz, DML31 and DML32 showed good activity only in broth extract. The crude broth and mycelia extracts of isolate DML 30 showed IC_{50} as low as 30 μg/mL and 7μg/mL respectively in NCIH460 cells. In 16S rDNA sequence analysis the isolate DML 30 showed close similarity to *Streptomycetes wuyuanensis*. Further isolation, purification and characterization of the lead compound are progressing.

Screening and isolation of Polyhydroxyalkanoate producing bacteria from Goa coast

Linu Balan*, Sowmya P. Mohandas, Rosamma Philip and I. S. Bright Singh
National Centre for Aquatic Animal Health, Cochin University of Science & Technology, Lake Side Campus, Kochi 680 016 Kerala, India. Email: linu.milan@gmail.com

Conventional petroleum-based plastics do not degrade and have an unusually long life span. They cause serious threat to environment by leaching out hazardous chemicals, animal deaths by entanglement and ingestion. PHAs from microorganisms are promising alternatives to petroleum derived plastics. They are produced by bacteria to store excess carbon when the nutrients are limited. They

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are biodegradable and biocompatible and have properties similar to petroleum based plastics paving way to applications ranging from packaging to drug delivery.

Although, several PHA producing bacteria have been isolated from terrestrial environments, not many studies have been reported from marine environment. This work focuses on screening, isolation and biochemical characterization of PHA producing bacteria from various marine samples collected from Goa coast, and estimation of PHA content from potent isolates. Bacterial Isolation was done on ZoBell's Marine Agar plates. Primary screening was done on modified medium incorporated with 2 % Glucose and Nile Red. The presence of PHA was confirmed on secondary screening by Nile Red staining. The PHA production was carried out by shake flask method employing two stage fermentation strategy. PHA content was estimated based on the percentage of crotonic acid present per unit cell dry weight and the potent isolates with high PHA productivity were selected and extraction was carried out. Identification of the isolates was done by biochemical characterization.

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MECOS 2 |MBTP 31

Isolation and characterization of a carotenoid producing novel *Micrococcus* sp. from Bengal corvina *Daysciaena albida* (Cuvier, 1830)

Susmitha, V.* Imelda Joseph and Anu Mathew
Central Marine Fisheries Research Institute, Koch 682 018, Kerala, India. Email: susmitha81@gmail.com

In the present study the screening of bacteria from the skin of Bengal corvine, *Daysciaena albida* (Cuvier, 1830) collected from Chennai coast (N- 12° 47.469'; E- 80°, 15.119'), Tamil Nadu, India, has led to the isolation of a yellow pigmented strain K-S2 (Fig.1). Cell morphology, motility and the occurrence of spores were examined by phase-contrast microscopy. The isolate was Gram-positive, spore forming, non motile branched cocci with colonies on nutrient agar yellow, opaque, circular and convex with entire margin. It was catalase positive and negative for oxidase. It was not H_2S producing, citrate utilizing, or casein, urea, starch or cellulose hydrolyzing. The strain was alkali-tolerant and extremely halophilic (upto 20 %). The isolate grew well in minimal media containing glucose, fructose and sucrose. The strain KS2 was identified as *Micrococcus* spp. based on the phenotypic characteristics and 16S rRNA sequence analysis (Fig.2).

Extraction and separation of the bacterial carotenoid was carried out by a one step methanol / hexane extraction. The coloured supernatant in hexane solvent was analyzed using UV- Visible Spectrophotometer from 350 -550nm range for detecting the λ_{max} (Fig 3). The bacterial pigment was identified as Neurosporene (λ_{max}=438°±2nm; %III/II=100). The pH of the medium and incubation temperature was found to be limiting factors in the growth of the bacterial strain. Fig.3 Three peak spectra of extracted carotenoid Fig.4 DPPH Staining Fig.5 Effect of pH on growth Recent reports have shown that the carotenoid, neurosporene,
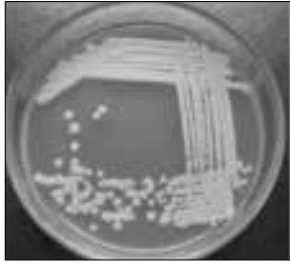
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Fig.1 Colonies on LB plate
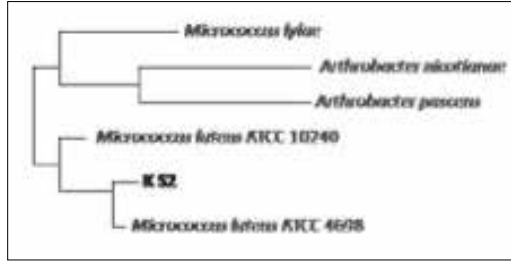
Fig.2 Phylogenetic tree based on 16S rDNA sequence analysis
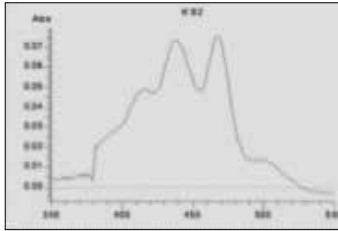
Fig.3 Three peak spectra of extracted carotenoid
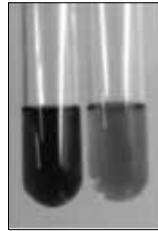
Fig.4 DPPH Staining
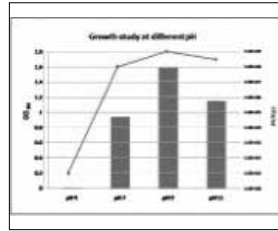
Fig.5 Effect of pH on growth

is of commercial importance due to its use as an antioxidant and UV-B radiation protector. The extracted carotenoid from the bacterial strain was investigated for the presence of the antioxidant (free radical scavenging) capacity using DPPH staining (Fig. 4). The color change from purple to yellow, which was measured spectrophotometrically emphasized that the carotenoid extract from the current isolate *Micrococcus* sp. had antioxidant potential.

MECOS 2 |MBTP 32

Molecular characterisation of ammonia oxidising consortium used for activating nitrifying bioreactors for developing recirculating aquaculture systems for non-penaids

Preena, P. G.* and I. S. Bright Singh
National Centre for Aquatic Animal Health, Cochin University of Science and Technology, Lake Side Camous, Kochi 682 016, Kerala, India. Email: preenabimal@gmail.com

The major limiting factor for the successful operation of prawn/shrimp hatcheries is the accumulation of NH_4^+-N to toxic levels.The usage of various bacteriological filters can solve this issue only to a limited extent. In this context, technology has been improvised to develop Packed Bed Bioreactor and Stringed Bed Suspension Bioreactor for establishing nitrification in prawn (non-penaeid, salinity 10–15 ppt) and shrimp (penaeid, salinity 30–35 ppt) larval production systems. Two nitrifying bacterial consortia Fig.1 Colonies on LB plate Fig.2 Phylogenetic tree

based on 16S rDNA sequence analysis (NBC) were developed from marine and brackish water systems for the application in tropical Recirculating Aquaculture System (RAS) in the activation of SBSBR and PBBR. Aim of the work described here was to determine the species diversity and phylogenetic divergence of ammonia oxidizing consortium generated for activating nitrifying bioreactors in recirculating aquaculture systems for non - penaeids.

DNA from ammonia oxidizing consortium (AMONPCU-I) was extracted, PCR product of 16S rRNA gene was cloned, 85 positive clones were selected, 16S rRNA gene reamplified and subjected to ARDRA using three tetra cutter enzymes, Alu I, Hae III and Hpa II, and the patterns were observed on 3 % agarose gel. Dendrogram generated using Ntsys software on the basis of ARDRA resulted in 18 clusters. Sequencing 16S rRNA genes of the representatives of the clusters resulted in the detection and identification of *Nitratireductor indicus, Nitrobacter* sp., *Arenibacter* sp., *Pelagibacterium halotolerans, Planctomyces* sp., *Filomicrobium* sp. *Spinghobacterium* sp., *Paenibacillus* sp., *Alcanivorax* sp., *Pusillimonas* sp. and several uncultured bacterial clones in the consortium.

The dominance of *N. indicus* highlighted the efficiency of the consortium for nitrate removal from the RAS thereby contributing to N cycle. The presence of *Nitrobacter* sp. demonstrated the ability of the consortium to perform nitrification. Anaerobic ammonia oxidation was also found to be possible within the consortium due to the presence of *Planctomyces* sp. The cultures of *Rhodococcus* sp., *Sphingobacterium* sp. and *Paenibacillus* sp. have been reported to be heterotrophic and aerobic nitrifiers in recent years. The occurrence of *Alcanivorax* sp., *P. halotolerans*, *Filomicrobium* sp., *Pusillimonas* sp. and *Arenibacter* sp. suggested the capability of hydrocarbon degradation of the consortium. In addition, diverse uncultured bacterial clones added a great deal of significance to the ammonia oxidizing consortium. Phylogenetic tree was constructed from aligned data sets of representative clones by neighbor-joining algorithm using Mega5.0 software. The study suggested that both the two step nitrification and subsequent denitrification were able to be accomplished using the same consortium in a single bioreactor, thereby eliminating the requirement of anoxic compartment in the reactor for denitrification.

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MECOS 2 |MBTP 33

Denitrification potential of *Vibrio fluvialis* isolated from different mangrove environments around Kochi, Kerala

Leo Antony, M. *, Anusree V. Nair, S. V. Sandhya and K .K. Vijayan
Central Marine Fisheries Research Institute, Kochi 682 018, Kerala, India. Email: augustusleo13@gmail.com

Nitrogen is one of the principal elements present in all forms of life. In both aquatic and terrestrial ecosystems, nitrogen circulates by means of microbial activity. Microorganisms have the capacity to uptake and assimilate both organic

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and mineral forms of nitrogen and play a vital role in the ecological balance of elements. However, the fixed nitrogenous forms like ammonium (NH_4^+), nitrate (NO_3^-) and nitrite (NO_2^-) ions are sometimes increasing in the aquatic environment, which in excess leads to serious environmental and health complications. In recent years, the intense aquaculture practices have led to increased nitrogen pollution in aquaculture ponds, mainly from the accumulation of uneaten feedstuffs and faeces. The treatment of culture water to decrease the polluted nitrogenous wastes becomes increasingly crucial. Physiochemical and biological methods are widely used in the treatment of polluted water. The advantage of using biological methods in treating the polluted water is that the residual pollutants can be completely removed without any secondary pollution but, it is not completely feasible as physical and chemical modes. The identification of microbes with the potential ability to perform denitrification simultaneously is found to be effective and have many applications in bioremediation. Many bacteria with the potential ability to remove inorganic nitrogen form to gaseous forms have been extensively investigated but the denitrifier that degrades NO_2^--N was reported very less.

Vibrio is a genus of gram-negative, rod shaped bacteria prevalent as both free living and surface attached in marine and related environments. Adaptation of this species to the fluctuating aquatic ecosystem and to their respective hosts is critical to their survival and colonization success. Despite the widespread presence in the marine environment and their genomic flexibility, many of its properties Fig.1 A. Growth curve of the isolates in the denitrification medium with nitrite as a sole nitrogen source. B. Reduction of nitrite-N by the activity of the isolates in the denitrification medium. Legend: Vf02; Vf03; Vf04; Vf05; Ps04; Ba37 are still underexplored. The present study was aimed to screen and characterize the simultaneous heterotrophic nitrification and denitrification potential of the four *Vibrio fluvialis* - Vf02, Vf03, Vf04 and Vf05 isolated from four different mangrove environments. Here, the denitrification potential of the *Vibrio* isolates was screened using plate assay. The isolates which showed positive results were screened for denitrification activity by growing in the liquid denitrification medium. The

Fig.1 A. Growth curve of the isolates in the denitrification medium with nitrite as a sole nitrogen source. B. Reduction of nitrite-N by the activity of the isolates in the denitrification medium. Legend: Vf02; Vf03; Vf04; Vf05; Ps04; Ba37

denitrification ability was analyzed using analytical methods. The isolates *Vibrio fluvialis* - Vf02, Vf03, Vf04, Vf05, and the *Bacillus subtilis* Ba37 and *Pseudomonas aeruginosa* Ps04 was characterised for nitrification and denitrification abilities. In the preliminary screening, the isolates showed positive green colour formation around the isolates, revealing the presence of denitrification activity. All test isolates showed stronger activity and good growth in the presence of nitrate as a sole nitrogen source. In the presence of nitrite-N, the isolates Vf03 and Vf04 showed similar and stronger potential to denitrify the toxic nitrite-N. All Vibrio sp. exhibited growth in the presence of nitrite-N, but other test genera such as *P. aeruginosa* (Ps04) and *B. subtilis.* Ba37 showed limited growth. In *Vibrio* sp. Vf03 and Vf04 nitrite-N was reduced at a rate of 2.223 & 2.12 mg/L NO2- -N/h with the removal efficiency of 52.18 % and 51.03 % respectively, showcasing the stronger denitrification activity of the *Vibrio fluvialis* isolates Vf03 and Vf04.
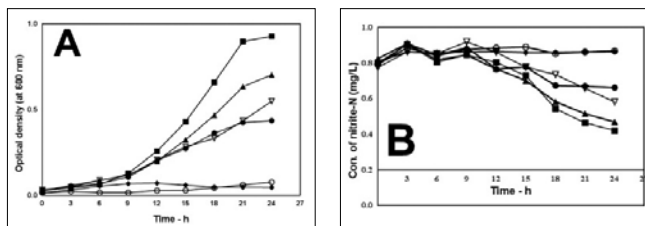
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Studies on the mineral changes in hepatopancreas, ovary and muscle during different maturity stages of the green tiger prawn *Penaeus semisulcatus* De Haan

Sivachandrabose, K.* and C. Suseelan
Thiruvalluvar University, Serkkadu, Vellore 632 115, Tamil Nadu, India. Email: drksivachandrabose@gmail.com

The present work was attempted to understand the mineral changes during different maturity stages of the green tiger prawn *Penaeus semisulcatus* collected from the fishing ground of Gulf of Mannar (Mandapam coast, Tamilnadu) which extended from Lat. 8˚50'N to 9˚40'E and Long.78˚35,E to 79˚40'E where the depth ranged between 15 and 50 meters. Dried tissue samples such as ovary, hepatopancreas and muscle of the various maturity stages of the female prawn collected were used for the analysis of magnesium, calcium, copper, manganese, zinc, nickel, lead, chromium and iron by using the triple acid extraction method as proposed by Jackson (1973). Flame photometry was used for the estimation of sodium and potassium present in the tissues. Among the various minerals Na, K. Ca, Mg, Cu, Mn, Fe, Zn, Ni and Pb whose presence was detected, K, Na and Ca were the most dominant constituents in all the tissues examined. In general, most of the elements were seen as the highest concentration in the immature stage, while in the different maturing and maturity stages their concentration was relatively low. Almost all the minerals except Ni registered maximum values in the ovary and particularly in the immature stage. Among the major elements, K, Na, Ca, Mg, and F were comparatively low during the various stages of the maturation and K and Na showed marked increase during the spent stage. In hepatopancreas, while the dominant elements K, Na and Ca recorded the highest values in the immature stage, Fe, Ni, Mg and Mn in the late maturing stage and Cu and Pb in the spent stage. The concentration of Cu, Zn and Fe was relatively high in the late maturing and mature stages. In muscle, K was the most dominant element at all the stages of maturation although its concentration in immature stage was minimal. All the other mineral values were at the lowest. The values of the Mn and Pb were below the detectable limit in different stages of maturity. Among the values recorded for Ca, Cu, Mn and Zn in muscle, higher values were recorded in immature, mature and spent stages. Other minerals viz. Na, K, Mg, Fe, Ni and Pb showed maximum values in early maturing stage. In total, the trend of mineral content in relation to maturity stages fluctuated. The variation of the result indicated that the muscle contributes to the inorganic matter build up in the ovary as well as the involvement of metabolic activity in all the stages of *P. semisulcatus*. It is inferred from the study that the variation of the mineral constituents in hepatopancreas, ovary and muscle showed their significant contribution during different maturity stages of the green tiger prawn *P. semisulcatus* De Haan.

RNA interference-mediated silencing of gonadinhibiting hormone (GIH) gene as an induce maturation strategy for captive penaeid broodstock development

Nithoon James, P. Saikrithi, Subhendu Kumar Otta, C. P. Balasubramanian, T. Subramoniam and Sherly Tomy*
Central Institute of Brackishwater Aquaculture, 75, Santhome High Road, Chennai 600028, Tamil Nadu, India. Email: sherly@ciba.res.in

Regulating the multi-hormonal pathways for captive maturation of penaeid broodstock is a critical factor in shrimp aquaculture. Oocyte maturation *In vivo* is a highly orchestrated, physiological process. Vitellogenesis in crustaceans is negatively regulated by gonad-inhibiting hormone (GIH) secreted from the X-organ sinus gland complex in the eyestalk. Unilateral eyestalk ablation practices in hatcheries lowers the levels of GIH, but eventually leads to loss in egg quality and severe stress on the spawners. The aim of the study was to establish an alternative method to reduce the GIH levels to induce maturation using Indian white shrimp, *Fenneropenaeus indicus* as a model. Short interfering RNAs (siRNAs) strategy was applied to study GIH knockdown efficacy and also to analyze their regulatory function on transcripts involved in reproduction. Treatment with 5 μg/g body weight of GIH-specific double-stranded RNA (GIH-dsRNA) resulted in a 2 fold decrease (70 %) in GIH mRNA expression together with significant changes in reproduction associated genes. The study highlights the potential of RNAi as an induce maturation strategy for captive broodstock development.

In vivo constructed gonad-inhibiting dsRNA mediated eyestalk neuropeptide gene knockdown in the tiger prawn, *Penaeus monodon*

Vrinda, S.*, Rosamma Philip and I. S. Bright Singh
National Centre for Aquatic Animal Health, Cochin University of Science and Technology, Lake Side campus, Kochi 682 016, Kerala, India. Email: vrinda.sukumaran @gmail.com

In recent years RNA interference (RNAi) has materialized as a powerful controlling mechanism of post transcriptional gene silencing in animals and plants. RNA interference is a phenomenon whereby double-stranded RNA triggers a potent and specific inhibition of its homologous mRNA; discovered by Andrew Fire and colleagues in 1998. Double-stranded RNA is introduced into animals and cells

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by injection, electroporation or chemically mediated transfection. The *In vivo* injection studies in animals require highly concentrated quantity of dsRNA, so that a simple and cost effective approach to produce long dsRNA will be useful for RNAi studies, especially in invertebrates. Several approaches have been used to synthesize long dsRNA using the commercially available kits based on the principle of *In vitro* transcription of linearized DNA template or PCR generated templates that are widely used. However, it is increasingly expensive to use kits, when one needs to produce large amounts of dsRNA for RNAi studies. The *In vivo* production of dsRNA in Escherichia coli strain HT115, which lacks ribonuclease III (RNase III) activity can be used as an alternative approach to produce large amounts of dsRNA at low cost.

In this study, we isolated the gonad inhibiting hormone gene, constructed the recombinant transcriptional vector (L4440 + PmGIH) and produced dsRNA in *E. coli* strain HT115. The silencing effect of GIH dsRNA was carried out in previtellogenic animals (n= 20, 15- 20 g). The physiological variations due to silencing of GIH genes were measured in the haemolymph as GIH concentration and vitellogenin/ vitellin levels using anti-PmGIH antibody and anti-vitellogenin/ vitellin antibody respectively. The physiological variations were due to GIH gene knock down was proved by semi-quantitative RT-PCR analyses and calculating the peak intensity of the GIH transcript and Vg gene expression. The GIH transcript expressions in the dsRNA injected animals were compared to the expression of GIH in the controls and to that of β-actin (house- keeping gene) to compare the level of expression. The level of knockdown of GIH transcript expression was proved by the above comparison.

The physiological and functional response of the animals to the application of dsRNA of GIH gene gives a broader picture of the expression of GIH hormone genes in *P. monodon*. The various parameters dealt with in this are essential for understanding the regulation of GIH hormone genes in view of its practical application. Another important feature of this piece of work is the *In vivo* production of dsRNA using bacterial system (*E. coli* HT115) that can be efficiently employed to produce large amounts of dsRNA with relatively low cost for RNAi studies. The large amounts required for silencing the specific gene *In vivo* can be effectively produced in this system. The cost for production of large amount of dsRNA can be reduced to one- third in comparison with that *In vitro*. The generation of dsRNA *In vivo* in bacteria is relatively simple and thus cost effective.

Differential expression of ovarian gene transcripts in *Fenneropenaeus indicus* following 5-hydroxytryptamine treatment

Saikrithi, P.*, Nithoon James, C. P. Balasubramanian and Sherly Tomy
Central Institute of Brackishwater Aquaculture, 75, Santhome High Road, Chennai 600 028, Tamil Nadu, India. Email: sherly@ciba.res.in

A prominent feature of crustacean ovarian maturation is the rapid accumulation of yolk protein, vitellin, the by-product of vitellogenin, in oocytes. 5- hydroxytryptamine (5-HT), a monoamine neurotransmitter, is involved in hormone biosynthesis, growth regulation, signal transduction and stimulation of ovarian maturation. A study was conducted to examine the effect of 5-HT on ovarian maturation of *Fenneropenaeus indicus*. 5HT was administered at a dose of 50 μg/g Body Weight to ablated and unablated female shrimps and observed for ovarian maturation for a period of 21 days. The potential effect of 5HT on maturation was examined by real-time PCR analysis of reproduction associated genes namely vitellogenin (Vg) and vitellogenin receptor (VgR). Oogenesis and cortical rod formation was confirmed by histological analysis. The result indicated a stimulatory role for 5HT in F. indicus ovarian maturation probably by activating the release of gonad-stimulating hormone. However, further research has to be implemented to analyze whether serotonin can generate a longer reproductive performance replacing eyestalk ablation.

Two-hybrid studies on interaction of proteins involved in neuroendocrine control of oocyte maturation in *Penaeus monodon*

Nithoon James *, P. Saikrithi and Sherly Tomy
Central Institute of Brackishwater Aquaculture, 75, Santhome High Road, Chennai 600 028, Tamil Nadu, India. Email: sherly@ciba.res.in

Gonad-inhibiting hormone (GIH) produced in the eyestalk X-organ sinus gland complex of penaeid shrimps play a prominent role in the regulation of Vitellogenesis. Although it has been postulated that GIH regulates production and release of hormones involved in reproduction, the mechanism by which they mediate their effect remains poorly understood. To determine the crucial mediators, Two Hybrid Assays were performed by constructing an ovarian cDNA library and screened against the bait (GIH). Initially auto-activation for the bait was validated and subsequently putative positive interactions were identified from the library based on beta galactosidase assay activity. Further studies have being initiated to confirm

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the novel protein partners involved in regulating oocyte maturation.

Purification of Phytase from a wild strain of *Bacillus* MCCB 242 to enhance phosphorus availability in fish nutrition

Sareen Sarah John* and I. S. Bright Singh
National Centre for Aquatic Animal Health, Cochin University of Science and Technology, Lakeside Campus, Fine Arts Avenue, Kochi 682 016, Kerala, India. Email: sareensj@yahoo.co.in

Phytate is the main storage form of phosphorus (P) in many plants and grainbased diets used in intensive livestock operations. Phytate is the most important anti-nutrient since it is found in grains, cereals, pulses and have a strong ability to complex multi-charged metal ions and make them unavailable for utilization to monogastric or agastric fishes. Phytate and its chelate cannot be degraded in aquatic animal intestines, and large amount of nutrients such as phosphorus and nitrogen are released into water bodies, which increases the eutrophication of water leading to environmental pollution.

Phytase (myo-inositol hexakisphosphate 3 phosphohydrolase) is an industrial enzyme that can break down the undigestible phytate which is the main form of phosphorus storage in cereals, pulses, grains, oil seeds and nuts. Phytase can be used to improve phosphorus bio-availability and have a wide range of applications in animal and human nutrition. Phytase also acts in the acceleration of hydrolysis to eliminate the phosphates from the phytate molecules and become utilizable to the fishes. The phosphorus availability in fishes increases when they are fed phytase-supplemented feed with plant raw materials.

With pressure to find more sustainable sources of fish feed for aquaculture, researchers have been trying to improve the nutritional value of fish feed by enzyme supplementation. It has been reported that enzymes can be used successfully to combat anti-nutritional factors in plant proteins for fish feeds. Phytase has been increasingly used in fish feed recently, mainly in response to heightened concerns over pollution to the aquatic environment. The increase in the demand for phytase has to be met by producing the same in a cost-effective manner using microorganisms. In view of this and to find alternatives to fishmeal, a study was undertaken to purify the enzyme produced by a wild isolate *Bacillus* MCCB 242.

A total of 110 microorganisms were isolated from farm soil, coir retting ground, marine sediment and were screened for their phytate degrading ability for commercial and environmental applications. Three isolates were found to be able to hydrolyze extracellular phytate. The enzyme was purified by ammonium sulphate precipitation, dialysed using Amicon stirred cells with a 10 kDa cut off membrane and DEAE cellulose chromatography. The enzyme activity was determined for crude sample and after every stage of purification. SDS PAGE analysis showed

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that the phosphatase corresponded to 43 KDa molecular mass. RTG 2 Cell lines (from gonad tissue of yearling rainbow trout (*Oncorhynchus mykiss*) were used to study the cytotoxicity of the purified enzyme. Cytotoxic effects were investigated at different concentrations of enzyme in the range of 0, 1, 3, 5, 10, 25, 50,100, 250 and 500 μg enzyme/ml. Even at the highest concentration of 500 μg/ml, no significant change in the cell morphology could be observed suggesting that the enzyme could be considered relatively non-toxic. It is envisaged that the phytase generated and purified in this study shall find commercial application as feed supplement for enhanced phosphorus uptake.

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MECOS 2 |MBTP 40

DNA barcoding confirms the occurrence of *A. dussumieri* in Cochin Estuary

Deepak Jose, V. S. Neethu, B. Nidhin and M. Harikrishnan*
Cochin University of Science and Technology, School of Industrial Fisheries, Lake Side Campus, Kochi 682 016, Kerala, India. Email: deepak87juv@gmail.com

In the present study, an effort was taken to collect samples of members of family Chandidae from fishery landings of Cochin estuary. On examining 95 individuals morphologically, 93 of them showed similarity. Body elongate, compressed with convex dorsal profile. Mouth moderate, jaws lower longer than upper; teeth small, villiform bands on jaws. Lateral line is interrupted. Scales in mid-lateral series is from 23-31 (Table.1). Eyes large. Dorsal fin deeply notched, VII and I spines and 8-10 soft rays in first and second parts and with a blackish mark on between 2nd and 3rd dorsal spines. Anal-fin with III spines and 8-11 soft rays. Caudal fin is forked. Pelvic fin has I spine and 5 soft rays while pectoral fin has 11 to 17 rays. Cheek and operculum scaly and cheek with 2 rows of scales. Gill rakers are 20-32 in number. Supra orbital is with 1-4 is backwardly directed spines. Preorbital ridge is smooth or with 2-3 small serrae. Preorbital edge with 4-7 spines strongly serrated, serrations being directed slightly backward and downwards. Preopercle ridge with 7-14 serrae, vertical border of preopercle is entire; lower edge of preopercle with 7-29 serrae. Interopercle smooth. Scales are large and cycloid, extending onto head and base of the median fins. These morphological characteristics corroborated to the descriptions of *Ambassis dussumieri* (Cuvier and Valenciennes, 1828). However, this species was not previously reported from the lake. The interrupted lateral line helped to distinguish it from three species of family Chandidae which are already reported from the lake, viz. *A. ambassis*, *Parambassis dayi* and *P. thomassi*. However, the morphological features of collected specimens showed similarity with *A. gymnocephalus* which reportedly constituted the bulk of landings from Vembanad Lake during eighties. Owing to taxonomic confusions in the morphological descriptions of *A. gymnocephalus*, molecular identification using DNA barcoding was attempted.

Nine trimmed CO1 sequence of *A. dussumieri* (Cuvier, 1828) were developed in the present study and were submitted to NCBI (National Center for Biotechnology

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Information) (Accession numbers KF770831, KF770832, KF770833, KF770834, KF781348, KF741349, KF 918315, KF918316, KF918317). Fig.2 depicts the molecular phylogenetic tree of neighbor-joining analysis with 1000 replications for *Ambassis* species based on Kimura 2-parameter substitution model. Distance matrix based on K-2-parameter showed that sequence divergence between *A. dussumieri* and *A. gymnocephalus* ranged between 10.80% to 11.80%. Within *A. dussumieri* individuals, sequence divergence ranged from 0.0% to 1.30% which contained under the threshold value of 3% for speciation according to Hebert et al. (2005). It could be discernible that *A. dussumieri* of Cochin estuary was very close to *A. gymnocephalus* and *A. miops* (Fig.1) since the COI sequences of these species got aligned within as sister clades with a common ancestry.

Table 1. Morphometric and meristic characteristics of *A. dussumieri* collected from Vembanad Lake (n=93)

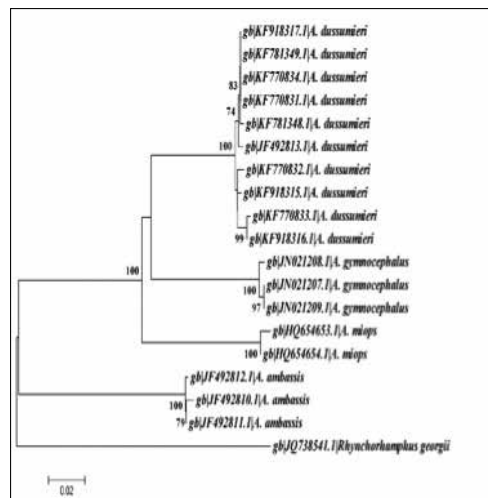|	Range	Mean± SD
TL (cm)	5.3-9.0	7.29 ±0.76
SL (cm)	4.2-6.6	5.47 ±0.54
Lateral line scales	23-31	27.66 ±1.61
Cheek scales row	2	2 ±0
Supraorbital spine	2-5	3.1 ± 0.59
Post orbital edge serrae	4-9	6.12 ±0.59
Post orbital ridge serrae	2-4	2.54 ±0.52
Preopercular Ridge	1-15	10.46 ±2.1
Lower edge of preopercle	13-29	21.09 ±3.17
Gill rakers	20-32	28.66 ±1.57
Pre dorsal scales	12-16	14.96 ± 0.9

Fig.1. Neighbour joining treee (1000 replications) for Ambassis sp. based on Kimura-2-parameter substitution model.

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Anticancer and antimicrobial activities of secondary metabolites produced by newly isolated marine Actinomycete strains from Saudi costal habitats

Wael N. Hozzein*, Sameh M. H. Khalaf, Elsayed A. Elsayed and A. M. Mohammed Wadaan
Bioproducts Research Chair, College of Science, King Saud University, P.O. Box 12455, Riyadh 11451, Saudi Arabia. Email: hozzein29@yahoo.com

Actinomycetes from the costal habitats of Saudi Arabia are not yet well explored, which represents a good candidate for isolation of new actinomycete strains for drug screening programs. For this purpose, eight samples were collected from the Arabian Gulf habitats in the Eastern Province of Saudi Arabia. The selective isolation of actinomycetes was carried out on three different recommended media. A hundred actinomycete strains were isolated and purified. Based on the dissimilarities in their appearance on two different media, twenty six strains were selected to study their diversity by examining their morphological characteristics and determining their cell wall diaminopimelic acid isomer type and whole-cell sugar pattern. The selected isolates were primarily assigned to 8 actinomycete genera, namely, *Micromonospora, Streptomyces, Nocardiopsis, Amycolatopsis, Microtetraspora, Nonomuraea, Actinopolyspora* and *Saccharomonospora*. These results showed that there is good actinomycete genus diversity in the Saudi costal habitats and some of the isolates could be classified as novel taxa. The taxonomic positions for sixteen strains were confirmed by the phylogenetic analysis of the 16S rRNA gene sequence. The selected sixteen strains were screened for their cytotoxic and antimicrobial activities. Seven strains showed promising activity against the tested Gram-positive and Gram-negative bacteria as well as yeast strains; namely *Bacillus subtilis, Staphylococcus aureus, Eschericha coli, Klebsiella pneumonia, Pseudomonas auerogenosa, Candida albicans* and *Saccharomyces cerevisiae*. In addition, the actinomycete extracts showed potent anticancer activities against human T cell leukemia (Jurkat) and human laryngeal carcinoma (Hep-2) cell lines. The results are encouraging and the active secondary metabolites are under chemical characterization studies now.

Taxonomic identity of *Portunus pelagicus* species complex in Indian waters using morphological and mitochondrial DNA markers

Jose Josileen*, A. Gopalakrishnan, P. R. Divya, V. S. Basheer and G. Maheswarudu

Central Marine Fisheries Research Institute, Kochi 682 018, Kerala, India. Email: drjoslin@gmail.com

Decapod crustaceans form a major component of commercial fisheries in the Indo-West Pacific region. Crabs, an important component of decapod crustaceans, are dominated by a few members of a single family, the Portunidae. *Portunus pelagicus*, commonly known as the Blue Swimmer Crab is widely distributed throughout the Indo-West Pacific region and there have been indications that it may be a species complex. Morphological examinations of *P. pelagicus* from different locations of India show that several distinct colour morphs exist. The present study was therefore initiated to determine whether *Portunus pelagicus* is a species complex, and if so, the number of species, the genetic identification using COI and 16s rRNA sequences and the morphological differences between them. For this, *P. pelagicus* were collected from different locations of Palk Bay and Gulf of Mannar, where the species forms a regular fishery and a dominant species in the landing. The samples were examined using DNA, morphometric and morphological methods. Accurate identification of these species is important for fishery management, as its morphological characters are very similar.

Based on morphological and mitochondrial sequences the present study clearly demarcates the existence of two species of Portunus ie., *Portunus reticulatus* and *P. pelagicus*, atleast in the areas covered under study. Analyzing COI gene (655 bp), the genetic distance of intra-species ranged from 0.002 to 0.005, while it varied from 0.059 to 0.062 for inter-species. The haplotype diversity and nucleotide diversity was found to be high, ie., 0.9590 and 0.04360 respectively. No insertions, deletions or stop codons were observed in any of the COI sequences. Of the 655 sites, 45, 41 and 4 were polymorphic, parsimony informative and singleton sites respectively. Analyzing 16S rRNA sequences (610 bp), the genetic distance of intra-species ranged from 0.005 to 0.009, while it varied from 0.024 to 0.038 for inter-species. Neighbor joining tree generated using COI and 16S rRNA sequences shows two clusters among Portunus species complex distributed along Gulf of Mannar and Palk Bay, cluster I of *P. reticulatus* and cluster II *P. pelagicus*) (Fig.1).
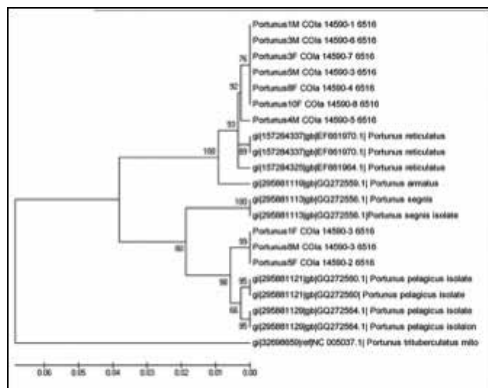

Fig. 1. NJ Tree generated using COI sequences shows similarity of cluster I with P.reticulatus and of cluster II with P.pelagicus.

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Notes on reproductive biology of the armoured shrimp *Glyphocrangon investigatoris* Wood-Mason and Alcock, 1891 inhabiting Bay of Bengal

Diana Benjamin*, M. Harikrishnan, Jenson Victor Rozario, Deepak Jose, U. Sreedhar, Sherine sonia Cubelio and Madhusoodhana Kurup
School of Industrial fisheries, Cochin University of Science and Technology, Kochi 682 016 , Kerala, India.
Email: dianabenjamin1484@gmail.com

The armoured shrimp *Glyphocrangon investigatoris* Wood-Mason and Alcock, 1891 has been reported to inhabit depths ranging from 145 to 410 fathoms in Bay of Bengal. There has been no published record of the biology of this species inhabiting Indian waters ever since its first report more than a century ago, based on the 'Investigator' expeditions. This paper gives detailed description on morphometry and egg number of female *G.investigatoris* caught along with deep sea Pandalid shrimps *Heterocarpus woodmasoni* and the
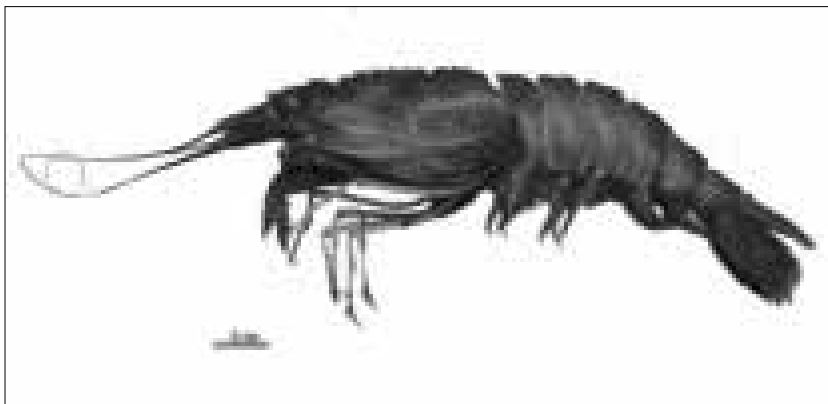

Fig 1.Lateral view of female *Glyphocrangon investigatoris*

Nephropid lobster *Nephropsis stewarti,* in FORV *Sagar sampada* from depths between 633-655 m using EXPO trawl, off Paradeep, Orissa (Lat.18°.48'.708 N, Long 85°.21'.605 E to 18°.54'.189 N, 85°.26'.898 E).These shrimps constituted 7.73 % of total catch from 633 m depth. 84 female specimens were collected and identified following the keys provided by Komai (2004). The females bearing ova in brood pouches were individually packed in polythene bags and were transported to laboratory to avoid egg loss. Individuals ranged from 29.0 -117.8 mm in total length with a mean value of 75.3 ± 23.5. The carapace length ranged between $17.29 – 36.31$ mm with a mean of 28.9 ± 3.87 mm while body weight varied between 2.28 to 16.54 g and the mean weight was estimated as 10.53 ± 3.43 g. Regression of carapace length of females on body weight showed a positive linear correlation ($r^2 = 0.85$). The growth in respect of weight in relation to carapace length was found to be negatively allometric ($p < 0.01$). The carapace lengths of

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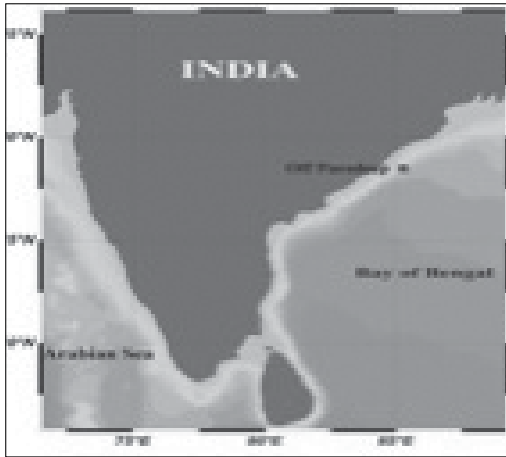
Fig 2. Map showing sampling areas of *G. investigatoris.*
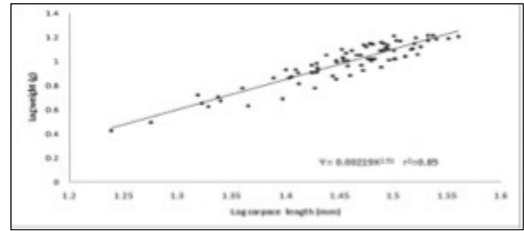
Figure 3. Relationship between Carapace length and weightin *G. investigatoris.*

smallest and largest egg bearing females were 20.80 and 35.57 mm respectively. The number of eggs in brood pouches varied between 50 to 233 (mean 120±41). Egg number revealed a linear relationship with both total length and carapace length.
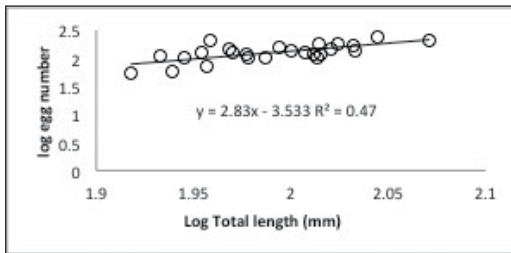
Fig 4. Regression of egg number on total length in *G. investigatoris.*
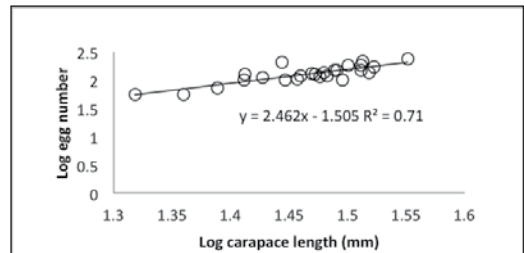
Fig 5. Regression of egg number on carapace length in *G. investigatoris.*

Livelihood and
Ecconomics

Track 6

A study on the role of microfinance on indebtedness in marine fisheries sector of Odisha

Vipinkumar, V. P.*, R. Narayanakumar, P. S. Swathilekshmi, and N. K. Harshan

Central Marine Fisheries Research Institute, Kochi 682 018, Kerala, India. Email: vipincmfri@gmail.com

The microfinance organizations and Self Help Groups mobilised in marine fisheries sector play vital role in reducing the indebtedness among marine fisherfolk. The study makes an attempt on the assessment of the extent of indebtedness among marine fisherfolk in mechanized, motorized and traditional fisheries sectors and the impact of Microfinance Institutions (MFI) on coastal indebtedness. The study was carried out in four coastal districts of Odisha state. Situational analysis was done through PLA in the selected locations and the sample respondents were selected from mechanized, motorized and traditional sectors. Data were collected through personal interview from members of 12 selected MFIs and non members in these sectors comprising a total of 600 respondents.

Table 1: Level of indebtedness and repayment

Sector	Indebtedness In lakhs (Rs)		% of Repayment	
	Non members	MFI	Non members	MFI
Mechanised	2.15	1.74	26.0	28.0
Motorised	1.83	1.43	29.0	31.0
Traditional	0.73	0.26	16.5	26.0

The results showed that the level of indebtedness of members of MFIs was less compared to the non members. Even if the indebtedness was more in certain cases, the repayment capacity was found to be significantly improved in MFIs. Private money lenders were the major source of credit followed by banks.

Fig 1: Sources of Credit across the state of Odisha

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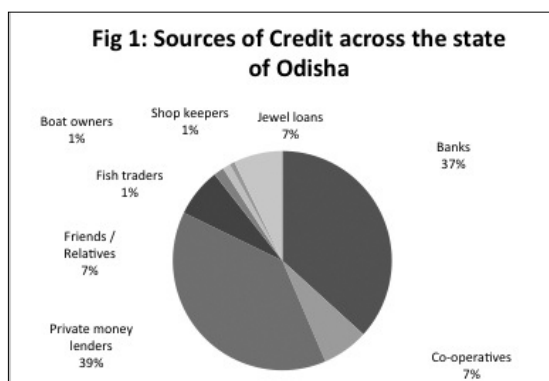
There is an extreme necessity of strengthening the MFI ventures in the traditional and tertiary fisheries sectors in the state. A comparative assessment of the sources of credit, the purposes of credit and the utilization pattern of loans in the state was also undertaken to draw valid conclusions. It was also found that the MFIs ranked better in most of the major attributes in the perception of stakeholders compared to banks and non-institutional credit sources. Success cases of MFIs on entrepreneurial capacity building, those significantly played the role in the debt redemption and poverty alleviation were documented as a practical manual for mobilizing MFIs in any key areas on a sustainable basis.

MECOS 2 |LESO 02

Open sea cage aquaculture - Inviting fisher youth to farming, in Kovalam, Tamil Nadu

Kizhakudan, J. K.*, K. K. Philipose, R. Sundar, V. Joseph Xavier, C. Manibal and R. Ponniah
Central Marine Fisheries Research Institute, Madras Research Centre, 75, Santhome High Road, Chennai 600 028, Tamil Nadu, India. Email: jkkizhakudan@gmail.com

Increasing seafood demand and intensification of mechanized coastal fishing activities have been taking a steady toll on not only fish stock but also on the sustenance of traditional and small scale fisheries along the coast of Tamil Nadu. This in turn is drawing fisher youth away from their traditional livelihood profession to go in pursuit of other opportunities. This will eventually impact the outlook of the fishing community towards sustainable fishing, as "conserving for the sake of posterity" will no longer remain a necessity. With growing impetus on marine aquaculture to augment seafood production in the light of stagnating catches, the Central Marine Fisheries Research Institute has been encouraging fishermen to take up open sea cage farming as an additional or alternate livelihood practice.

Kovalam fishing hamlet in Tamil Nadu is one of the focal points of CMFRI's initiative towards this. As a continuous process of reviving and retaining interest among fisher youth, CMFRI has been conducting awareness and demonstration programmes on seafarming and habitat restoration. A team of fifty young fisher youth (below 30 years of age) were encouraged to form the Association of Kovalam Progressive Fishermen (AKPF) with the approval of Kovalam fisher and Panchayat leaders. These boys were trained in all aspects of sea cage culture operations, from cage fabrication to harvesting and live marketing.

Two GI cages of 3 m outer diameter (OD)/2 m inner diameter (ID) and 5 m OD/4 m ID were fabricated. The smaller cage with a net enclosure of 2 m diameter and 2 m depth was operated for spiny lobster fattening, while the bigger cage with a net enclosure of 4 m diameter and 3 m depth was operated for sea bass growout. Four members of the AKPF were involved in the lobster fattening venture while sea bass cage culture was done by ten members.

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About 180 rock spiny lobster *Panulirus homarus* (48-49 mm CL and 100-110 g weight), collected from bottom set gill nets operated in the coastal waters off Kovalam and adjacent reef areas were stocked in the cage at a stocking density of 30/sq.m. The initial floor space in the cage was 3.1 sq. m. Secondary bottom layers and suspended vertical screens were used to get a total floor space of 6 sq.m. About 60% of the lobsters stocked were males. The inner cage depth was maintained at 2.5 m and outer at 3 m from the lowest level of the floats. The cage was covered using bird nets and the animals were fed twice *ad. libitum* with market offals from estuarine tilapia and other discards from the trammel net and cast net fishery in the backwaters. After 30 days of culture (DOC) size range was 52-54 mm CL and 132-137 g weight and at final harvest, after 50 DOC, the sizes recorded were 54-56 mm CL and 140-180 g. The average rate of growth in size was nearly 0.14 mm increment per day and 1 g increment per day in weight. The net survival was 81%. The total biomass produced was 26.67 kg and the selling price was Rs. 1,200 per kg. The value realized from auction proceeds was handed over to the Association and their members.

The bigger cage was moored at a site of 8 m depth, about 1km from Kovalam shore. The cage was stocked with 1500 fingerlings of Asian sea bass *Lates calcarifer*. The average size at stocking was 60 g. Culture operations were carried out for a period of 100 days, using low cost tilapia caught from the backwaters of Muthukadu, as feed. The harvested biomass was 600 kg, with a survival rate of 80%. The harvested sizes ranged between 0.44 to 1.1 kg, with an average size of 0.5 kg. The cultured fish was sold live to a recreational sport fishing agency in Chennai @ Rs. 400/- per kg and a sum of Rs.2, 40,000/-was realized by the AKPF from the sales. The fish were transported live with no mortality, by road, for over an hour, and transferred to the freshwater facility at the sporting zone.

Highlighting the interest of stakeholders towards sustaining fishery resources, the members of the AKPF, along with Kovalam fisher leaders and the trader who had purchased the harvested seabass for sport fishing, with the help of the CMFRI team from Chennai, released adult broodstock of seabass, sand lobster and ten pounder raised in captivity at the Kovalam field Laboratory of CMFRI, back into the sea off Kovalam as a "re-wilding initiative".

One of the advantages of live marketing for sport fishing is that the grow-out period can be shortened since demand on size is less. New marketing avenues with a higher value realization have opened new vistas in open sea mariculture in India.

Fig. 3 Director, CMFRI hands over sale proceeds

Fig. 4 Commissioner of fisheries, TN flags off sale to AKPF members of live seabass

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Sardine Economy of Kerala - Demand and Supply Paradigms

Shyam S. Salim*, R. Narayanakumar, Ramees Rahman. M and Bindu Antony

Central Marine Fisheries Research Institute, Kochi 682 018, Kerala, India. Email: shyam.icar@gmail.com

Kerala is endowed with rich fisheries resources. The state reflectsa high fish consumption pattern, which projects the unique case of balanced fish demand and supply over many decades. The fisheries sector contributes to around 8 percent of the total fish production in the country and is the third largest fish consuming state with more than 85 percent of the population consuming fish. The annual per capita consumption of an average Keralite is around 27 kg which accounts for over three quarters of the animal protein intake. Among the different fishes consumed in Kerala Sardine,Sardinellalongiceps, the staple fish of Kerala, a rich source of omega 3 fatty acid is considered as a low cost delicacy , and is termed as "candidate poor men's protein", owing to timely availability , easy accessibility and sufficient affordability. These characteristics leads to price stabilization of sardine due to identified /well defined /informed demand and supply relationship unlike other fishes. Sardine demand is characterized by domestic and international requirement,raw material for fish feed and bait industry. The state's domestic sardine supply is met by landings in Kerala and the neighboring states mostly Tamil Nadu, Karnataka, Andhra Pradesh and Maharashtra.

In the recent times there exist numerous demand and supply constraints resulting in exorbitant price rise, competition amongst different users and non-availability of the species. Sardine is exported to Middle East countries where there exist a significantKeralite population in addition to Israel and Malaysia. There exists considerable demand for sardine in fish meal (5 percent) and bait industry (10 percent) in Asia- Pacific region. The average decadal sardine landings in Kerala tends to be around 2.50 lakh tonnes which is around 55 percent of the total sardine landings in the country. A time series analysis of oil sardine landings of Kerala during 1985 to 2013 indicated wide fluctuations even along an increasing trend. During 2012 sardine landings reached its peak of 3.93 lakh tons(32 percent of the total catch of Kerala), however showed drastic decline in the following year with a catch of 2.04 lakh tons record catch of sardines.

Recently, the price of sardine almost quadrupled resulting in shortage of sardine in the market and created concerns for fish food security for the consumers. The present study is an attempt to analyze the sardine economy of Kerala by assessing the demand and supply pattern and the possible demand-supply gap expected in the future years. The study was conducted by collecting primary data on sardine consumption vis-à-vis fish consumption demand estimates across 600 households from three metropolitan cities of Kerala, viz; Trivandrum, Cochin, and Calicut using a structured survey schedule. Data on sardine arrivals from the different states and preferences in its selling over other species were collected from 60 fish traders. The

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results indicated that the average per capita consumption of sardine was found to be 8.2 kg which constitutes around 30 percent of the total fish consumption in Kerala. The demand for sardine for the different time periods indicated that the sardine demand would hover around 3.05to 4.25 lakh tonnes for the period during 2015-2035, but with competitive demand from the export, feed and bait industry there could be a demand supply gap of 0.50 to 2.50 lakh tonnes during the period.

There is much divergence in the quantity of sardine demanded and supplied, thus creating the demand-supply gap (Fig. 1).The non-availability of fish in the domestic fish market might lead to fish food security concerns wherein the domestic consumers could be devoid of fish in the market at affordable prices and at timely intervals. The study also indicated that around 100-150 tonnes of sardine arrives daily into Kerala mostly from Tamil Nadu, Andhra Pradesh and Karnataka. The traders preferred to sell sardine over mackerel, thread fin breams, anchovies, shrimps and other fish species on account of popular demand even across different income strata. The results alarm the immediate need to regulate sardine utilization in terms of exports, fish meals and live bait. In addition concerted efforts in regulating juvenile fish catch study
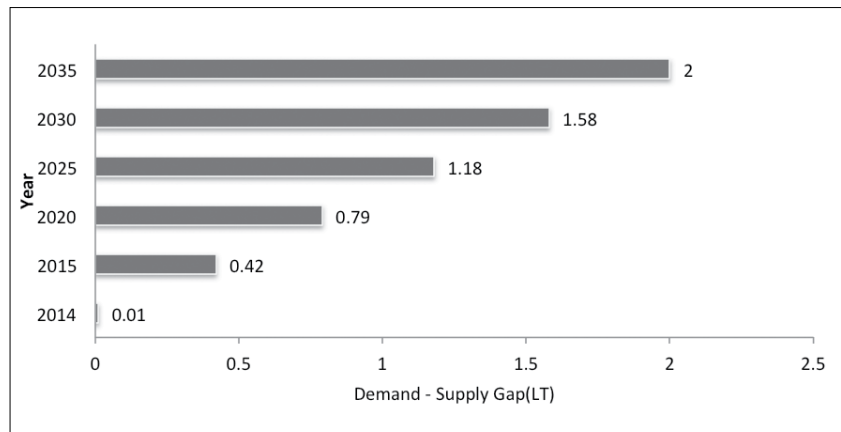
Fig. 1. Projected Demand — Supply gap in lakh tons (LT) over the years

MECOS 2 |LESO 04

Farming of seaweed in Tamil Nadu coast - Economics and constraints

Johnson, B.*, G. Gopakumar, R. Narayanakumar, I. Rajendran and P. Kaladharan
Central Marine Fisheries Research Institute, Mandapam Regional Centre, Mandapam Camp 623 520, Tamil Nadu, India. Email: jsfaith@gmail.com

Commercial cultivation of *Kappaphycus alvarezii* was started in 2005 along the Tamil Nadu coast. At present, *K.alvarezii* production is carried out in five coastal

districts of Tamil Nadu namely Ramanathapuram, Pudukottai, Thoothukudi, Thanjavur and Kanyakumari. The study with an expost-facto research design was undertaken in Ramanathapuram district of Tamil Nadu coast where seaweed farming and collection is adopted in larger scale. Moreover, seaweed farming was adopted first in this district. Among the 184 villages in Ramanathapuram district, seven villages namely Vedalai, Munaikadu, Mandapam, Pamban, Olaikuda, Sambai and Mangadu were selected for the study, since the area and number of rafts used for seaweed farming is more compared to other villages, moreover seaweed collection is done in all these villages. A total of 500 sample farmers (which includes 100 seaweed collectors) were selected through proportionate random sampling technique. Data collection was done through interview method. Data were subjected to percentage analysis.

Majority of seaweed farmers are using 25 to 45 rafts for their cultivation. Due to lack of space for the farming, in majority of the villages a farmer is restricted to use maximum of 45 rafts only. The unit cost per bamboo raft for *K. alvarezii* farming works out to be 1000. Average yield per raft (12 x 12 feet) is 240 to 260 kilogram. They retain 60 kilogram as planting material for the next crop. If 240 kg of seaweed is dried, it results in 24 kg dry weight. The current prices are 3.50 per kilogram on wet weight basis and 27.50 per kilogram on dry weight basis. A fisherman family earns around 11,400 per month (if hired labour is engaged @ Rs. 150 per raft). Nearly one-third of the seaweed farmers earn an average monthly and annual income of Rs. 12,000 and Rs. 96,000 respectively. It is interesting to note that about 20 percent of seaweed farmers left fishing and involved only in farming and wild collection of seaweed. Remaining 80 percent of the farmers involved in both fishing and seaweed farming.

This trend shows that any lucrative option like seaweed farming which can supplement the capture fisheries is readily accepted and adopted by the marine fisherfolk. About 80 percent of seaweed farmers had expressed that during the month of May – June, the grazing intensity was more, which affected the yield up to 50-80 percent. Diseases are caused by low salinity, high temperature, and less light intensity. About three-fourth of the seaweed farmers have expressed that when temperature was high (more than 30°C) the plant was under stress, whitening of the branches occurred, which resulted in crop loss. During the month of August and September, 2013 heavy loss of *Kappaphycus alvarezii* was reported in and around Ramanathapuram district. More than 10,000 rafts which were ready for harvesting were completely decayed due to high temperature and the economic loss was about 37.5 lakhs. Even few farmers discontinued the farming due to severe loss during high temperature period. After that loss now farming is slowly progressing in the area.

Gender integrated value chain analysis of a women enterprise on fresh fish processing

Ashaletha, S*., M. Nasser, K. V. Lalitha and V. Geethalekshmi
Central Institute of Fisheries Technology, Kochi 682 029, Kerala, India. Email: ashalethasuresh@gmail.com

The core concept of the agricultural value chain is that the different actors are connected at different levels along a chain producing and delivering goods to consumers after undertaking a sequence of activities. Following the World Bank's concept of 'full range of value adding activities required to bring a product or service through the different phases of production, including procurement of raw materials and other inputs', a fish value chain was established under the World Bank funded National Agricultural Innovation Project, "Responsible Harvesting and Utilisation of Selected Small Pelagics and Freshwater fishes". Under the project, value chain based model rural enterprises were initiated involving women as major players.

Value chains, when established within a given social context, influence the distribution of resources, employment/ entrepreneurial trends and opportunities. These can have positive or negative and direct or indirect consequences on the actors. In general, value chains offer tremendous opportunities to the stakeholders through more employment, business opportunities and better market linkages. But in some cases, it can affect the actors as well as the business environment negatively also.

In this paper, the results of a study conducted on the effect of the fish value chain established based on marine small pelagic fishery on the women actors is presented. The study could establish that women in coastal belt are to be integral part of any fish value chains. It revealed the ways in which gender involvement influenced the Relational value chain established under the project and how their lives were influenced by the way the value chains function. While discussing the Gender Integrated Value chain Analysis (GIVA), the paper also brings to light how important is gender in value chains and the extent of contemplations which should take place while planning & establishing value chain with active involvement of women. The role of various factors like gender relations at the household level play in deciding the extent of gender involvement in value chains is another important aspect dealt with. The paper would be much help to those who look forward to establish gender integrated value chains in any commodities

An economic assessment of production potential and resource use efficiency of marine capture fisheries in Thoothukudi district, Tamil Nadu

Radhakrishnan, K, Swadesh Prakash, R. Narayanakumar, M. Krishnan, M. S. Madan*, Nalini Ranjan Kumar and T. Umamaheswari
Central Marine Fisheries Research Institute, Tuticorin Research Centre, Thoothukudi 628 001, Tamil Nadu, India. Email:madan.cmfri@gmail.com

World marine fisheries contributes significantly to the global economy and act as a sunshine sector for poverty alleviation and food production sector. Marine fisheries have been contributing to livelihood, income generation and employment opportunities to coastal districts. India is relatively rich in marine fish production and the sector showed a significant growth both in terms of quantity and quality. Enhanced demand and supply of fish and fishery products resulted in rapid expansion in marine capture fisheries. The fastest growth in marine fisheries has been achieved through modernization of fishing equipments and technology advancement. Though the fishing vessels are being operated with same level of inputs, the economic performance as well as technical efficiency is not found to be uniform. Efficient fishing along with well-regulated management system through fisheries governance is a pre-requisite for sustainable fish production. To cope up with this, the present study attempts to analyze and compare the investment, financial and techno-economic performance and level of efficiency of mechanized, motorized and traditional fishing vessels of Thoothukudi district. By adopting simple random sampling technique, the data was collected from 40 fishers each from mechanized, motorized and traditional fishing vessels of Thoothukudi district using a pre-designed survey schedule. The financial feasibility of the three sectors was assessed using Net Present Value (NPV), Pay Back Period (PBP) and Benefit Cost Ratio (BCR). By adopting Flaaten et al. (1995) method, cost and returns analysis was carried out. Economic performance was assessed using Profit margin referred as the ratio of net profit to gross revenue. Financial performance (Return on owner's capital) was calculated as rate of profit to total owner's capital of the vessel. Multiple linear regression analysis was done to know the efficiency of the fishing vessels.

The results revealed the NPV for mechanized, motorized and traditional fishing vessels at Rs.33.84 lakhs, Rs. 1.13 and Rs. 0.02 lakhs, respectively. The BCR for three types of fishing vessels were good, but seems to be higher for traditional fishing vessels (1.16%) as compared to mechanized (1.13%) and motorized fishing vessels (1.11%), because of the greater discounted stream of benefit. The net profit was of Rs.9.13 lakhs, Rs. 0.85 lakhs and Rs. 0.18 lakhs in mechanized, motorized and traditional fishing vessels, respectively. But, the economic performance was found to be higher in traditional sector (20.94%), followed by motorized (14.11%) and mechanized sector (10.47%). Financial performance was good and higher for mechanized fishing vessels (58.34%). For traditional sector, catch per man day was 5.27 kg, which was lower, when compared to motorized (14.26kg) and

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mechanized (83.39 kg) fishing vessels. Labour wages and annual fishing days were the common gross revenue determinants across the three sectors. From the present study, it has been concluded that, economic performance was found to be higher in traditional fishing vessels with less net profit, whereas, financial performance and technical efficiency has registered well in mechanized fishing vessels than motorized and traditional fishing vessels. Also, it was found that greater economic returns (Thoothukudi district) have been achieved through efficient implementation of Tamil Nadu Marine Fisheries Regulation Act.

MECOS 2 | LESP 02

Techno-economic performance of mechanised fishing in Karwar, Karnataka

Aswathy, N.*, R. Narayankumar, K. K.Philippose, C. Ulvekker and N. K. Harshan
Central Marine Fisheries Research Institute, Kochi 682 018, Kerala, India.
Email:aswathy.icar@gmail.com

The techno-economic and financial performance of mechanized purse seiners and trawlers operating in Karwar fishing harbour in Karnataka was compared using various indicators. The trawlers and purse seiners in Karwar harbour operated for singleday only. The purse seiners had an overall length (OAL) of 45-50 ft with engine capacity varying from 104 - 140 hp, whereas the trawlers had OAL of 32 ft with engine horse power ranging from 40-60 hp. The diesel consumption per trip was 81 litres for trawlers and 179 litres for purse seiners. The average operating cost and gross revenue per trip were Rs.15, 909 and Rs.24, 704 respectively, for purse seiners and Rs.4, 823 and Rs.5,071 respectively for trawlers. Oil sardines and mackerels contributed more than 85 percent of the catch of purse seiners whereas shrimps and flatfishes contributed nearly 50 percent of the catch of trawlers. The capital productivity was higher (operating ratio -0.64) for the purse seiners than the trawlers (operating ratio-0.95). The economic and financial performance indicators like net profit-earnings ratio (22%), IRR (78%) and return on investment (27%) were higher for the purse seiners which indicated that the investment on purse seiners as a more viable undertaking when compared to single day trawl in the harbour. The study also indicated the scope for enhancing the revenue from fishing and income earning capacities of fish workers in the harbour through improvements in fish marketing and shifting to alternate avocations like sea cage farming which is getting prominence in the location.

MECOS 2 | LESP 03

Wooden canoe based small scale fishery: A socio-economic profile of fishermen in south west coast of India and Lakshadweep

Chithrakala, K. L*, K. A. Roshan, James J. Pulikotti , Nikita Gopal and Leela Edwin
Central Institute of Fisheries Technology, Matsyapuri, Kochi 682 029. Email: chithrakalakl@gmail.com

In India 26% of the 1,94,490 fishing crafts are non-motorized. Majority of the non-motorized crafts are engaged in small scale fisheries and they range from traditional catamaran to plank built boats, dhonis and dugout canoes. The study attempts to assess the socio-economic conditions of small scale fishermen operating wooden canoes in the south west coast of India and Lakshadweep. A structured questionnaire was used for a sample of 200 fishermen. The study shows that *Artocarpus hirsutus* (aini), *Mangifera indica* (mango tree), *Calophyllum inophyllum* (punna) were mostly used for canoe construction. Sixty eight percent of the fishermen owned the canoe, while others operated wooden canoes on share basis. Fifty seven percent of the fishermen were between the age group of 40-50 and majority of them had completed primary education. The daily income of the fishermen varied from Rs.200 - 1,200. Despite changes in the sector, the livelihood of the small scale fishermen tended to be vulnerable.

MECOS 2 | LESP 04

Economic efficiency of different fishing vessels in Thoothukudi coast, Tamil Nadu

Radhakrishnan, K, R. Narayanakumar, M. Krishnan, M. S. Madan*, Swadesh Prakash and Nalini Ranjan Kumar
Central Marine Fisheries Research Institute, Tuticorin Research Centre, Thoothukudi 628 001, Tamil Nadu, India. Email: madan.cmfri@gmail.com

In the present paper, attempts have been made to evaluate the economic efficiency of mechanized, motorized, and traditional fishing vessels in Thooothukudi coast of Tamil Nadu. Data were collected from 40 fishers from all the three sectors, through fine-tuned pre-designed interview schedule by simple random sampling. While the economic efficiency has been assessed through key economic indicators based on catch (kg), fuel (litre), values (Rupees), costs (Rupees) and crew; technical efficiency employs data envelopment analysis to evaluate the overall efficiency of the fishing vessels. Quantity of fish produced (per man per day) being one of the key economic indicator, has been valued at 5kg in traditional, 14kg in motorized

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and 83kg in mechanized fishing vessels. The fuel cost per kg of fish in mechanized fishing vessels was higher (Rs. 39.85) than motorized fishing vessels (Rs. 9.81). Likewise the total cost per kg of fish was lower in traditional (Rs. 19) than those of motorized (Rs. 29) and mechanized (Rs. 208) fishing vessels. However, the technical efficiency of mechanized fishing vessels has been found to be good and higher with more than 70% of the fishers falling under 0.9 to 1.0 technical efficiency range, as compared to 40% of motorized and 35% of traditional fishing vessels. This signifies that the mechanized fishing crafts have an edge over others in terms of productivity.

MECOS 2 | LESP 05

Adoption, technology transfer and performance evaluation of pearl culture technology at Sipikulam, Tuticorin - A case study

Jagadis, I*, V. Kripa, T. Mohanraj, H. Sivanesh, and G. Uma
Central Marine Fisheries Research Institute, Tuticorin Research Centre, Tuticorin 628 001, Tamil Nadu, India.
Email: iyaduraijagadis@gmail.com

CMFRI has developed many technologies for breeding, seed production and farming for many commercially important mollusks. One of them is the marine pearl culture technology. The technology has been developed way back in 1973 and has undergone refining for transfer to entrepreneurs. It was also partly transferred to fisher folks through NGOs like MSSRF, at Mundalmunai Village, Mandapam. The present attempt details adoption of village, feasibility study for pearl culture, development of infrastructure, training imparted and skill evaluation for follow up with State Fisheries Department for funding, to continue the project.

Accordingly a village, Sipikulam, Tuticorin was selected and a team of 7 women (age 18 to 35) and a male member were identified. Complete infrastructures like farm implements (raft size 5x5m), nucleation facility (surgical sets, glassware, plastic wares) were provided from the project. An old building provided by the village was converted into nucleating facility. Two trainings on surgical nucleation, fabrication of farm implements such as cages and rafts were imparted to the group. The trained fisher folks were evaluated for their skill acquired by test implanting and survival assessment (Table 1). After which they are allowed to carry out the entire process of continued nucleation, farming, harvesting and grading of pearls produced. The trained group was capable of producing 5.2 % commercial grade pearls (Table.2). The success of the implementation of the project was evaluated by variable indicators of 0-5 point scale, which showed suitability and capacity building of the village. As an encouragement/proof of their skill, the product was given to the team. A proposal was also prepared for the follow up and continuance of the culture activity and handed over to the group and a strong linkage was developed by liaising the group with the State Fisheries Department.

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Table I.   Nucleating potential of trained beneficiaries - Sipikulam (Spherical Nucleus)

S.No.	Beneficiary	No. of implanting days	No. of oysters implanted	No. of live oysters
1	Mrs. Sangeetha	101	675	251
2	Mrs. Regina	29	197	55
3	Ms. Vinnarasi	107	1021	308
4	Ms. Sindhuja	106	839	337
5	Mrs. Thilagavathi	22	185	120
6	Mrs. Jayarani	36	162	70
7	Mrs. Rani	36	192	80

Table. 2. Details of results of pearl production trials by the beneficiaries of Sipikulam village

S.No.	Trained beneficiary	No. of implantation	% of oysters survived	% retention	% quality pearls in survival
1	Mrs. Sangeetha	675	20.5	28.8	6.4
2	Mrs. Regina	197	30.4	3.3	1.6
3	Ms. Vinnarasi	1021	26.4	18.1	7.7
4	Ms. Sindhuja	839	27.9	23.1	6.9
5	Mrs. Thilagavathi	185	40.0	17.6	0
6	Mrs. Jayarani	162	41.9	23.5	4.4
7	Mrs. Rani	192	11.9	13.1	4.3

MECOS 2 | LESP 06

Value chain in mullet farming in Kerala: Scientific gaps and potential

Vikas, P. A.* and Shinoj Subramannian
Krishi Vigyan Kendra (Ernakulam) of ICAR-Central Marine Fisheries Research Institute, Narakkal,
Kochi 682 505, Kerala , India. E mail: vikaspattath@gmail.com

Brackish water finfish farming is getting momentum in Kerala due to ever increasing demand for fish as a nutritional food. Low return from shrimp aquaculture is also a reason for development of finfish farming. Mullet and Pearl spot are the premium choice for the brackish water finfish farmers of Kerala owing to high price and market demand. There is very high demand for seeds of both these fishes particularly during October - November as license for aquaculture commence from 15th of November. Wild collected seeds are the only source for Mullet (*Mugil cephalus*) as there are no commercial hatcheries functioning. Thirty to forty groups of traditional fisher folks were identified near Vypin area in Ernakulum who carries out collection of Mullet fry's from specific locations in sea during the onset of monsoon (Fig 1).

The fry's of 1 to 2 cm size and 200-300mg weight are collected using 6mm mesh cast net. These groups have indigenous know-how and specific skills in

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Fig 1. Month wise mullet seed collection details (%)
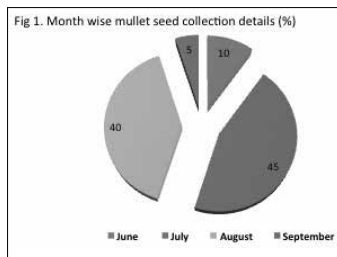
■ June ■ July ■ August ■ September

Fig 2. Collection and sorting of the of the Mullet fry's from the sea shore by the fisher folk

identification of the Mullet in fry stage. During the process they release other fishes larvae back to sea as a tradition (Fig 2). Average annual seed collection per group ranges from 20,000 to 40,000 and a total of 12 to 13 lakhs seeds were marketed by these groups during last season. The price varies from Rs. 4.00 to Rs. 7.00 per fry. Seed stocking is the main challenge faced by them due to the lack of enough space and this causes mortality. Middlemen who possess stocking space get profit due to this situation. Creation of centralized facilities for making seed banks of Mullet fry's near by the seed collection area are required to enhance the survival percentage, health status and return from the collected seeds. This also would facilitate getting quality larvae for the farmers.

MECOS 2 | LESP 07

Studies on market structure and constraints of ornamental fish enterprise in Ratnagiri district, Maharashtra state

Bhatkar, H. R., Bharat M. Yadav*, M. M. Shirdhankar, S. S. Gangan, A. K. Balange and R. M. Tibile
Central Institute of Fisheries Education, Versova, Mumbai 400 061, Maharashtra, India.
Email: cpbharat@gmail.com

Ornamental fishes are referred to as the jewels of aquatic body for their shape, tiny size and bright color. Ornamental fish are today the world's most popular pets and fish keeping is the second most popular hobby after photography. Availability of skilled manpower, well established communication network, international airports and export promotion zone (EPZ) provide vast scope for the promotion of ornamental fish trade and export. The domestic trade of aquarium is reported to grow at 20% annually. The present study was carried out in the Ratnagiri district of Maharashtra state to analyse the present condition of market, their structure and constraints of ornamental fish enterprise. A total of 71 numbers of ornamental fish entrepreneurs were surveyed.

The study showed that, the high percentage of ornamental fish entrepreneurs undertook rearing of fish as a major activity followed by retailing and breeding. Ornamental fish enterprise of Ratnagiri district showed three market intermediaries.

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These were rearers, retailers and breeders. Four marketing channels were observed in ornamental fish enterprise of Ratnagiri district. The fishes like Gold fish, angel and guppy showed adequate demand in ornamental fish market of Ratnagiri district as compared to other fishes. Majority of the ornamental fish entrepreneurs of Ratnagiri district were procuring fish from Mumbai wholesale market followed by Ratnagiri breeding and rearing enterprise. The maximum number of ornamental fish entrepreneurs (93.62%) sold their fishes in local market and the rest in both local and regional market. Almost 95 % of ornamental fish enterprises used their own finance for establishment of unit.

Major constraints faced by ornamental fish entrepreneurs were non-availability of technical advice followed by non-availability of special trainings and insufficient live feed. Other constraints faced by ornamental fish entrepreneurs were brood stock availability, non-availability of loan, non-availability of crop insurance schemes, heavy mortality losses, poor transportation facility and low selling price. Long marketing chain, absence of electricity subsidy, poor demand, lack of price and market information, high freight charges, insufficient infrastructure and inadequate space were the remaining constraints. Frequency distribution and percentage analysis were the key statistical techniques used. The non-parametric test such as $\chi2$ (Chi-Square) test and Sign test were employed to test the significance difference. The pie diagram, simple bar diagram and percentage bar diagram were used to represent the data.

MECOS 2 | LESP 08

Role of fisherwomen of Pulicat Lake, Tamil Nadu region - issues and perspectives

Lita Sunder* and K. Mahesh Kumar
Marine Studies & Coastal Resource Management Department, Madras Christian College, Chennai 600 059, Tamil Nadu, India. Email: lita_sunder@yahoo.co.in

The fisheries sector is an important source of livelihood for millions of people around the world. A large population of women work in the fisheries sector. They are engaged in a wide range of activities in the fisheries and in fishing all around the world. The exact nature of their work differs by regional, cultural and socio-economic factors. By and large the fisherwomen have remained as "invisible workers".

In India, women are not engaged in active marine fishing activity but play the major labour force in allied activities. They are involved in routine domestic chores and community tasks considered to be insignificant. The role of women as support to seagoing spouses was found to be both very important and highly undervalued by the fishing community. Though the fishing activity is carried out by men, the cleaning, processing and marketing of fish is mostly done by women. The job is highly demanding and involves long hours of work. As a homemaker, they play multidimensional roles which focus on health, sanitation and education of children and family members thereby, playing an indirect role leading to the improvement

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in the quality of life among fishing communities. The women are also directly involved in processing and marketing of fishery products.

The present study examined the roles of fisherwomen of Pulicat Lake fishing community. An analysis was performed of the obstacles and the potential related to women's contribution to the socio-economic development and diversification of these communities. It also identified the ways and means for the promotion of equal opportunities for women in the fisheries sector.

MECOS 2 | LESP 09

Traditional knowledge on crab harvesting and processing by the Nicobari tribes of Car Nicobar

Dam Roy, S., T. Ravikumar, Nagesh Ram, Raymond Jani Angel, R. Kiruba Sankar* and P. Krishnan
Central Island Agricultural Research Institute, Port Blair, A&N Islands 744 101
Email: rkirubasankar@gmail.com

The Nicobari tribes are one among the six native tribes of Andaman and Nicobar Islands (ANI) namely Jarawa, Sentinels, Onges, Andamanese and Shompens. This ANI archipelago consists of 572 islands including small rocks; islets etc. out of which 38 islands are inhabited. The Nicobari population mostly depends on plantation crops and fishing for their livelihood and restricted to Nicobar district. The study was aimed to document the harvesting and processing practices of terrestrial crab (Discoplax hirtipes (Dana, 1852) practiced by Nicobari tribes of Car Nicobar Island traditionally by employing their Indigenous Technical Knowledge (ITK). This terrestrial crab is appearing in bulk quantity on the jungle and road sides of Car Nicobar Island immediately after the beginning of southwest monsoon with peak in the month of June after the sunset. The crabs are found congregating like mounds along the root zone of mangrove trees and this is a strong indication of migratory and breeding behaviour of the crab. The season lasts for few months and huge harvest made from end of May to July of every year. These edible crabs were harvested by using their ITK in live condition by hand picking, wooden tongs made of thin bamboo or cane, hand glove made of piece of jute sack and cotton and iron rod. Usually Nicobarese moves in a group for harvesting the crab and 10-50 kg of crabs were harvested in few hours with the help of head light, torch light and kerosene light. The picked crabs were collected in jute sack and transported to their home by using bicycle, motorcycle and four wheelers. The transported crabs are stored in the baskets, plastic or iron barrels, aluminium utensils and four wheeler tyres for few days in live condition. During the storing time the crabs are fed with leaves and coconut pulp. Later, on need basis crabs are prepared in a traditional style and consumed along with main dishes such as rice, roti, Pandanus (Kewdi), Nicobari aloo etc. Coconut is one of the very important ingredients used for preparation of most of their traditional dishes from crab. The very common traditional dishes prepared include crab chutney, crab reha, crab soup, crab gravy, steamed crab etc.

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Fishing practices of Nicobari tribes of Munak Island

**Ravikumar, T., Nagesh Ram, P. Krishnan, R. Kiruba Sankar* and
S. Dam Roy**
Central Island Agricultural Research Institute, Port Blair, A&N Islands 744 101
Email: rkirubasankar@gmail.com'

The Andaman and Nicobar Islands (ANI) are broadly divided into Andaman group of Islands and Nicobar group of Islands and are separated by 10 degree channel. The Nicobar group of Island is further divided into North, Central and Southern Nicobar Islands. Northern most Island is called Car Nicobar which is the capital of Nicobar district located 75miles south from Little Andaman. The Southernmost Island is Great Nicobar situated about 100 miles from Sumatra Island of Indonesia. The central part of Nicobar Islands are called Nancowrie group of Islands positioned in the Northeast Indian Ocean between Andaman Sea and Bay of Bengal. The study was conducted to document the fishing practices of tribal fishers of Munak Island (Lat: N 08'800.331' and long: E 93'31.679') which is the integral part of Nancowrie group of islands. The inhabitants of this island are called Nicobari tribes who are Mongoloid origin. Fisheries is the second most important component of the islanders next to agriculture.

The fishers in this island are generally practicing Indigenous traditional Knowledge for capturing of fishes from the inshore waters. The fishing gears such as spear (single pointed and multi pointed), harpoon, hook and line, cast net, gillnet, fish trap etc. are very commonly observed in this study area. The spear, harpoon and trap were commonly made by them by using the available forest resource to capture fishes, octopus, crab etc. from near shore waters. In this island the fishers fish only for their own household consumption and in case of getting higher catch they distribute amongst themselves. Fishes, octopus and crabs are the main harvest from the sea. The common fishes landed in these islands include carangids, scombrids, shoal forming fishes like sardines, silver bellies etc. The traditional craft employed for capturing of fishes called Hodi, is an Outrigger Canoe. This craft is made from a single log by scooping out the wood and requires considerable traditional skill. Traditional dishes prepared include crab chutney, crab reha, crab soup, crab gravy, steamed crab etc.

Cage farming as an alternate sustainable livelihood opportunity for coastal communities in India

Philipose, K. K.*, Jayasree Loka, S. R. Krupesha Sharma, Senthil Murugan, N. G. Vaidya, S. M. Sonali, Narasimhulu Sadhu, K. Srinivasa Rao, and Praveen Dube
Central Marine Fisheries Research Institute, Karwar Research Centre, Karwar, Kodibagh 581 301, Karnataka, India. Email: kkphilipose@gmail.com

Open Sea cage farming of finfish and shellfish was successfully established in India by Central Marine Fisheries Research Institute (CMFRI), Government of India. Karwar Research Centre of CMFRI developed and perfected the designing of steel floating cages of different sizes and also standardized the farming technology of cage farming of marine finfish, for expansion of cage culture of marine finfishes along the Indian coast. Due to their high growth rate in shortest time and also of high economic value, farming of marine fin fishes viz., Asian Sea bass, Lates calcarifer, Cobia, *Rachycentron canadum*, is being practised by Self Help Groups of fishermen from Karnataka, Maharastra and Goa states as part of participatory programmes initiated by CMFRI. Under this programme, five fishermen Self Help Groups were identified from each state and 20 fishermen in each group were selected and were trained on various technologies developed in marine cage farming at the Karwar Research Centre of CMFRI. The financial assistance for these programmes was made available from RKVY, NPM and NFDB schemes through the concerned State Fisheries Departments. The centre has provided all technologies related to cage farming and also assisted in nursery rearing of fish seed of sea bass and cobia required for cage farming. Stocking density of fish in each cage was 2000 numbers / 6 m dia cage. The fishermen groups successfully cultured the fish in marine cages in all the three states with a production varying between 6-7 t for cobia whereas it varied between 5 - 7 t for Asian seabass, at the time of harvest.

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