Book of Abstracts & Lead Articles

The Second International Symposium | January 15 to 17 Kochi, India

SAFARI

Remote Sensing for Ecosystem Analysis and Fisheries

ICAR CMFRI

Organised by:
Indian Council of Agricultural Research
Central Marine Fisheries Research Institute

Societal Applications in Fisheries and Aquaculture using Remote Sensing Imagery

The Second International Symposium

Remote Sensing for Ecosystem Analysis and Fisheries

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सी एम एफ आर आइ
CMFRI

ICAR-Central Marine Fisheries Research Institute

Kochi, Kerala, India

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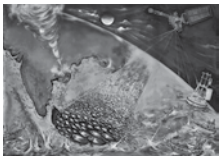

A Safari from Space to Ocean

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Foreword

It is with great pleasure that I pen this foreword for the book of abstracts for the SAFARI 2 symposium. Being a fish geneticist with little scientific exposure to satellite remote sensing applications, I used to wonder about the relevance of satellite data to marine fisheries. After assuming charge as the Director, ICAR-CMFRI, I had the opportunity to work with scientists who had initiated remote sensing related work on marine ecosystems and it was a revelation to me. My predecessor, Dr. G Syda Rao, implemented the flagship programme of CMFRI based on satellite remote sensing applications, technically known as Chlorophyll based Remote sensing assisted Indian Fisheries Forecasting System (ChloRIFFS), which became the forerunner for a series of small projects and later few major research programmes in CMFRI. In a happy coincidence, Prof. Trevor Platt FRS, globally renowned scientist in the field of Ocean Colour was awarded the prestigious DST-Jawaharlal Nehru Science Fellowship (JNSF) and he, along with Dr. Shubha Sathyendranath, another stalwart in Ocean Colour studies, chose CMFRI as their research centre in India. We were already in preliminary stages of collaboration with Space Applications Centre, Ahmedabad (ISRO-SAC), National Remote Sensing Centre, Hyderabad (ISRO-NRSC), and a few related organizations engaged in remote sensing studies in the country, and the introduction of JNSF at CMFRI widened our area of scientific interaction in the international arena. Now I can proudly say that we have an international consortium of scientists, including CMFRI scientists, working on satellite remote sensing applications with relevance to fisheries and aquaculture.

During a discussion with Prof. Platt, he mentioned about the SAFARI programme and the first international symposium he organized with the help of ICAR-Central Institute of Fisheries Technology (CIFT) in India. He expressed his concern at the lack of enthusiasm in conducting subsequent symposia to keep the scientific community updated about the developments in the field as well as to delineate plans to serve the society better using this knowledge. He put forth his vision to set up a secretariat for SAFARI at CMFRI, Kochi and the relevance of this in the current scientific scenario. The provision in DST-JNSF scheme to conduct a scientific gathering to disseminate the technical acumen received as part of the project to a wider audience added thrust to this thought and there was no doubt that CMFRI, being the host organisation of DST-JNSF, has to take a lead in organizing it. I was sceptical at the beginning, but continued interaction with CMFRI and international scientists convinced me of the importance of this symposium.

There is a need in marine fisheries research to supplement existing *in situ* measurements with synoptic data to fill in the gaps and information on the vast spatial oceanic basins can be generated only using satellite remote sensing data. I was able to inspire some scientists at CMFRI to take up research programmes in related areas and those who acquired technical skills in this were given a chance to develop human resources equipped to address issues in marine fisheries through satellite remote sensing applications.

Our history of association with satellite remote sensing related applications dates back to the MARSIS programme where we worked in collaboration with ISRO-SAC, which later paved way for the modern day Potential Fishing Zones (PFZ) that is being put into operation by INCOIS. We have been working in tandem with ISRO-SAC and later with INCOIS for refining and improving the PFZ. Further, we have put our efforts into analysing potential harvestable yield estimations of Indian

EEZ and optimization of fishing fleets with the support of ocean colour data through ChloRIFFS, our flagship programme. The success of ChloRIFFS motivated us to utilize satellite remote sensing data for identifying potential sites for cage mariculture, marine spatial planning, addressing fluctuations in the fishery, climate change related issues affecting marine ecosystems, prediction of environmental variables for developing adaptation strategies for the future, primary, secondary and tertiary production as well as fish biomass estimation, reef bleaching events and the science behind it, and many more related challenges. The information generated on a synoptic scale is depicted using geographical information systems. A feather was added to our cap with the endowment of a major DST-NERC co-funded INDO-UK project in collaboration with CSIR-NIO and PML, UK for generating *Vibrio cholerae* outbreak alerts based on inputs received from satellite remote sensing.

Recently, we have initiated some training programmes of short and long durations for developing our own man power and to disseminate the new knowledge to other organizations. With this confidence, I decided to go ahead with the conduct of the SAFARI 2 symposium at CMFRI and we started our efforts in this direction last year.

We were generously supported internationally by Nansen Scientific Society, Norway; Nansen Environmental Research Centre India, Plymouth Marine Laboratory, UK; NF-POGO Alumni Network for Oceans (NANO), UK and scientific partners of Prof. Platt, and at the national level by ICAR and its Institutes, ISRO and its Institutes, Earth System Science Organization and its Institutes, NABARD, NBA, MPEDA, FSI, DRDO, NIFPHATT, CSIR-NIO, KUFOS and State fisheries department of Kerala. The enthusiasm shared by the State Government in propagating the advancements in remote sensing technology is evident from the immediate consent I gained from the Fisheries minister of Kerala, Smt. J. Mercykutty Amma for the conduct of a special stakeholder session on disaster management. INCOIS, the operational organisation for dissemination of remote sensing based advisories also joined hands with us, making the interactive session with fisherfolk and other stakeholders of fishery community a reality. May the recommendations that arise out of this special session be of advantage to the vulnerable coastal communities.

I gratefully remember the sincere efforts put in by my colleagues and scientific partners in making this event a reality. I hope that "societal applications" in the expansion of the acronym SAFARI holds true and the new ideas generated as part of this symposium will take this concept forward and immensely benefit the country and its science.

The recommendations generated during the deliberations are going to elevate the user communities of satellite remote sensing applications related to aquatic ecosystems and fisheries to the next level in fulfilling their commitment to society. I fervently hope that the benefits accrued from this symposium will be used for establishing a scientific society with a secretariat for the furtherance of research in this field and to disseminate this technology to society. I thankfully acknowledge the generous funding and support received for this programme and take it as an approval from the scientific community to meet this aim. I thank the participants and experts attending the symposium and wish them a good time in Kochi.

10 January 2018

A. Gopalakrishnan
(Convener, SAFARI-2 & Director, CMFRI, Kochi)

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JUSTICE (Retd.) P. SATHASIVAM
GOVERNOR OF KERALA

RAJ BHAVAN
KERALA

03 January 2018

Message

I am very happy to know that the Central Marine Fisheries Research Institute, Kochi intends to bring out a Souvenir in connection with its 2nd International Symposium (SAFARI-2) to be held from 15th to 17th January 2018 at Kochi.

I wish the Symposium as well as the publication all success.

[Justice (Retd) P. Sathasivam]

राधा मोहन सिंह
RADHA MOHAN SINGH

D.O. No. 51 /AM

सत्यमेव जयते

कृषि एवं किसान कल्याण मंत्री
भारत सरकार
MINISTER OF AGRICULTURE
& FARMERS WELFARE
GOVERNMENT OF INDIA

03 JAN 2018

Message

India is the second largest fish producing country in the world. The vast aquatic and marine resources present in the country offer opportunities and potential for further development in the fisheries sector, if the nation uses available resources judiciously. In this context, it is very essential to be aware about modern scientific methods for resource conservation to ensure that our fisheries and aquaculture sector are economically sound, socially relevant and environmentally sustainable.

I am happy to learn that important issues would be deliberated during the second international symposium on "Societal Applications in Fisheries and Aquaculture using Remote Sensing Imagery (SAFARI-2)" with the theme of "Remote Sensing for Ecosystem Analysis and Fisheries" during 15-17 January, 2018 being organized by ICAR- Central Marine Fisheries Research Institute, Kochi. The symposium will be of great national and international significance for both scientific and fishing communities.

I hope the deliberations at the symposium will bring forth updated knowledge on sustainable management practices of fishery resources for scientific communities, fishery managers, policy makers and fisher folk.

I wish the symposium a grand success.

Radha Mohan Singh

(Radha Mohan Singh)

PINARAYI VIJAYAN
CHIEF MINISTER

GOVERNMENT OF KERALA

Secretariat
Thiruvananthapuram-695 001

No.12/Press/CMO/18.

January 03, 2018.

Message

I am happy to note that the Central Marine Fisheries Research Institute, Kochi is organising an International Symposium on the Societal Applications in Fishery and Aquaculture using Remote Sensing Imagery (SAFARI-2).

The fact that you are organising such a symposium in your Platinum Jubilee year is a testimony of your commitment to research in marine fisheries. I hope that this symposium will make a serious contribution towards enriching the knowledge currently available to the general public and the academic community in the field of marine fisheries.

I wish the symposium all the best.

(Pinarayi Vijayan)

त्रिलोचन महापात्र, पीएच.डी.
एफ एन ए, एफ एन ए एस सी, एफ एन ए ए एस
सचिव एवं महानिदेशक
TRILOCHAN MOHAPATRA, Ph.D.
FNA, FNASc, FNAAS
SECRETARY & DIRECTOR GENERAL

भारत सरकार
कृषि अनुसंधान और शिक्षा विभाग एवं
भारतीय कृषि अनुसंधान परिषद
कृषि एवं किसान कल्याण मंत्रालय, कृषि भवन, नई दिल्ली 110 001
GOVERNMENT OF INDIA
DEPARTMENT OF AGRICULTURAL RESEARCH & EDUCATION
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INDIAN COUNCIL OF AGRICULTURAL RESEARCH
MINISTRY OF AGRICULTURE AND FARMERS WELFARE
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Dated the 4th January, 2018
New Delhi

Message

The fisheries sector in India has made brisk strides in recent years, playing an important role in national food security, generating abundant employment opportunities, and raising national agriculture income through domestic marketing and foreign exchange. However, fishery resources all over the nation are suffering due to heavy exploitation and environmental degradation. Since fisheries and aquaculture are sunrise sectors for the nation, it is our earnest duty to ensure sustainability and efficient management of fisheries, while minimising the strain on natural resources.

I am delighted to know that the ICAR-Central Marine Fisheries Research Institute (ICAR-CMFRI) is organizing the Second International Symposium on Societal Applications in Fisheries and Aquaculture using Remote Sensing Imagery (SAFARI-2) on the very important theme of "Remote Sensing for Ecosystem Analysis and Fisheries" during 15-17 January, 2018. The organization of this symposium is very timely and it would have the desirable impact at the national and international level. The symposium is expected to provide solutions for achieving our goal of sustaining the fisheries sector, maintaining sound health of the oceans, enhancing input use efficiencies, and applying environmentally sustainable conservation and aquaculture practices. I am happy to note that the theme of the symposium has been designed in such a way that it will cover the most pertinent issues in the context of overall development of advanced remote sensing technologies for marine ecosystem analysis and fisheries.

I hope that the deliberations during the symposium will adequately highlight holistic development, and stimulate demand-driven research programmes with applications in the fisheries science.

I congratulate ICAR-CMFRI for shouldering the responsibility of organizing this symposium and wish the endeavour every success.

(T. Mohapatra)

डॉ. जे. के. जेना
उप महानिदेशक (मत्स्य विज्ञान)
Dr. J. K. Jena
Deputy Director General (Fisheries Science)

भारतीय कृषि अनुसंधान परिषद
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Message

Fisheries and aquaculture offer an attractive and promising sector for employment, livelihood and food security in several countries including Indian. Being an important source of protein, fish commands huge demand if made available in proper quantity and quality. For meeting the ever growing demand, effective and sustainable management of fishery resources is required at the national and International levels. Remote sensing technology enables the monitoring of marine ecosystems from space, and can be effectively used for harvest and post-harvest management. The use of innovative technologies related to remote sensing will enable fishers to track the movement of fish schools and quantify fishery resources in a more precise manner thereby empowering better harvest and management protocols at the fishing level itself.

I am very happy to know that ICAR-Central Marine Fisheries Research Institute (CMFRI), Kochi is organizing the 2nd International Symposium on Societal Applications in Fisheries and Aquaculture using Remote Sensing Imagery (SAFARI-2) at the Institute on a very important theme of 'Remote Sensing for Ecosystem Analysis and Fisheries' during January 15-17, 2018. I expect the output of the Symposium to be highly valuable in updating the scientific knowledge base on harvest fisheries management in the fisheries sector and will help to improve the socio-economic status of the fisheries community.

I congratulate the organizers for their efforts and wish for all success of the Symposium.

5/1/2018

(J.K. Jena)

सत्यमेव जयते
आई. रानी कुमुदिनी, भा. प्र. से
मुख्य कार्यपालक

NFDB
राष्ट्रीय मात्स्यिकी विकास बोर्ड
National Fisheries Development Board
कृषि एवं किसान कल्याण मंत्रालय, भारत सरकार
स्टॉप संख्या -२३५, फिश विल्डिंग, हैदराबाद - 500 052

04 January 2018
Hyderabad

Message

I am happy to know that the "2nd International Symposium on Societal Application in Fisheries and Aquaculture using Remote Sensing Imagery (SAFARI -2)" is being hosted by ICAR- Central Marine Fisheries Research Institute, Kochi, Kerala, as part of its 70th Anniversary Celebrations. On this occasion I would like to extend my warm greetings to the Director and Scientist for this initiative and efforts.

It is heartening to note that CMFRI is completing 70 years of service during which period pioneering research was undertaken not only on the biology of marine species contributing to pelagic and demersal fisheries but also on marine bio-diversity, stock assessment, estimation of potential yields from Indian EEZ, catch statistics and marine fisheries census of the country. Further, technologies developed by CMFRI for Mariculture of promising fish and shellfish species would go a long way in sustaining fisheries in the country.

Indian Space Research has advanced by leaps and bounds and Remote Sensing Technology is being used to map, manage and augment production and productivity of agriculture and allied sectors. Remote Sensing Tools have been gainfully employed by CMFRI for studies on Primary Productivity, determining Potential Fishing Zone (PFZ), etc., of our Seas and I am pleased to note that their use in 'Ecosystem Analysis and Fisheries' will be deliberated in the proposed Symposium of SAFARI-2.

I am confident that the outcomes of SAFARI-2 would throw more light on the dynamics of fishable stocks in the Seas around India and stimulate further research to realize the goal of sustainable marine fisheries in the country in the years to come.

I wish the Convener and the Organizing Committee Members of SAFARI-2 a grand success.

(I. Rani Kumudini)

समुद्री उत्पाद निर्यात विकास प्राधिकरण
(वाणिज्य व उद्योग मंत्रालय, भारत सरकार)
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Message

Earth observation by remote sensing is increasingly becoming a tool for improving fisheries and aquaculture planning, regulation and management. It is becoming a handy tool for providing advance notice to the fishery sector for locating fish shoals as well as to issue advance warning on natural calamities etc., offer exciting ways for societal benefits. A combination of Remote sensing and Geographical information System finds applications in fisheries and aquaculture. I am very happy to note that the Central Marine Fisheries Research Institute (CMFRI) has taken the initiative to organize the Second International Symposium on Societal Applications in Fisheries and Aquaculture using Remote Sensing Imagery from 15-17 January, 2018, at Kochi. I am sure that the Symposium will offer new insights into the application of Remote sensing technology in fisheries and aquaculture and pave way for societal benefits.

I wish the International Symposium all success.

(Dr. A. Jayathilak, IAS)
Chairman, MPEDA

तपन मिश्रा
निदेशक
Tapan Misra
Director

भारत सरकार GOVERNMENT OF INDIA
अंतरिक्ष विभाग DEPARTMENT OF SPACE
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Message

Evolution of Indian Space Missions comprising a fleet of earth observation, satellite communication and navigation payloads have made a phenomenal change in the usage of space technology for societal benefits including space-based earth observations and services for marine environment, Satellite remote sensing have improved our perspective of the oceans to a level unimaginable by earlier generations. Remote sensing data are provided in near real-time to help fishing community for fuel saving; to and to scientists for improved forecast and development of strategies for sustainable fisheries management.

Space Applications Centre (SAC) is one of the major Centre of Indian Space Research Organisation (ISRO), primarily entrusted with the task of conceptualisation, designing, developing and realization of all payloads besides developing and demonstrating several applications, SAC is involved in developing state of the art technologies for ocean colour remote sensing, atmospheric correction models, understanding coastal carbon dynamics in oceans, study of nitrogen cycle and phytoplankton blooms, fish stock assessment, modelling of primary and new production, management of marine living resources, species specific fisheries forecast and conservation for engendered marine organisms. Societal benefits from these exercises are many fold.

It is a matter of great pride that SAFARI (Societal Applications in Fisheries and Aquaculture using Remote Sensing Imagery) programme is being conducted for the second time in India and under the efficient leadership of ICAR-CMFRI, who has joined hands with ISRO to conduct advanced research for assimilation of satellite derived parameters in fishery and aquaculture applications, I am sure that SAFARI-2 will emphasise the enormous potential of satellite remote sensing to benefit society through application to fisheries and aquaculture, contemplating the importance to maintain the integrity of the structure and function of the ocean ecosystem.

I wish grand success to the Symposium.

तपन मिश्रा
(Tapan Misra)

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भारतीय कृषि अनुसंधान परिषद
कृषि अनुसंधान भवन –II
पूसा, नई दिल्ली – 110 012

Message

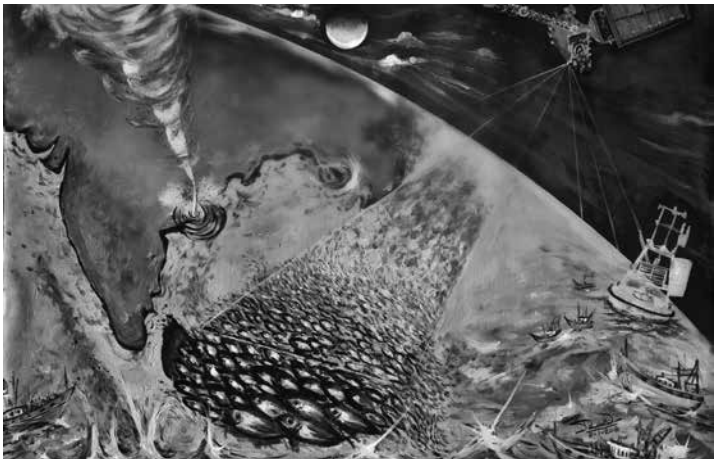
It gives me immense pleasure to know that ICAR-Central Marine Fisheries Research Institute, Kochi is organizing the second International Symposium of Societal Applications in Fisheries and Aquaculture using Remote Sensing Imagery (SAFARI-2) on an important theme of "Remote Sensing for Ecosystem Analysis and Fisheries" during 15 – 17 January 2018 as part of the celebration of the 70th Anniversary of the Institute.

Remote sensing observations are essential to study the large-scale dynamic variability in the aquatic and marine ecosystem. Understanding ecological functions is needed for sustainable management of fishery resources. The themes of the symposium are pertinent in the context of the overall development of advanced remote sensing technologies for aquatic and marine ecosystem analysis. It is also very crucial to be aware of the resource-conserving modern scientific methods to remain economically sound, socially relevant and environmentally secure.

This International Symposium will be a meeting point of scientific communities working in various aspects of fisheries and remote sensing from the country and abroad. This occasion would be platform for exchanging and cultivating new theories and ideas to bring out key issues and challenges in the sector.

I compliment ICAR-CMFRI for shouldering the responsibility of organizing the symposium on satellite based application for sustainable fisheries management and wish the programme a grand success.

(P. Pravin)



Keynote & Lead Articles

Lead Article
Sess: 1a/SI

SAFARI- A retrospection and future plans

Grinson George[1]*, Minu P. [1], Nandini Menon N.[2], and Gopalakrishnan A.[1]

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Ocean ecosystem monitoring on a synoptic scale helps us to learn the response of marine ecosystems to global warming. This can be attained with the aid of remote sensing, which provides an appropriate window into the ever-changing ocean ecosystems. The benefits of using remote sensing from an ocean colour perspective includes the capacity for regular monitoring of water quality in coastal habitats and detecting the initiation and senescence of all harmful algal blooms, including the subset of harmful algal blooms. This technology also serves conservation strategies for example, for delineation of marine protected areas. Remote sensing can contribute to i) fish stock assessment, particularly to understand the effect of seasonal and inter-annual variability in the phytoplankton community on the recruitment and growth of stock; ii) in fisheries harvesting by identification of suitable fishing grounds and thereby reducing fishing effort and increasing yield per unit effort; and iii) in ecosystem-based fisheries management by providing information on the dynamics of phytoplankton that are the base of all pelagic food chains.

SAFARI (Societal Applications in Fisheries and Aquaculture using Remotely-Sensed Imagery) is an initiative which provides a forum for coordination, at the international level, of activities in global fisheries research and management. The forum is open to all interested parties, including policy makers, research scientists, government managers, and those involved in the fishing industries. SAFARI organizes international workshops and symposia as a platform to discuss the latest research in Earth observation and fisheries management, information sessions aimed at the fisheries industry, government officials and resource managers, representation at policy meetings, and producing publications relevant to the activities. SAFARI gains worldwide attention through collaboration with other international networks, such as ChloroGIN (Chlorophyll Global Integrated Network), IOCCG (International Ocean-Colour Coordinating Group), POGO (Partnership for Observation of the Global Oceans) and the oceans and society: Blue Planet Initiative of the intergovernmental organization, the Group on Earth Observations (GEO).

Since its inception in 2007, SAFARI was incorporated into the activities of GEO, which has the objective to build a Global Earth Observation System of Systems (GEOSS) that is tailored for the needs of the user communities, and SAFARI is now recognized as a part of GEO's Blue Planet initiative. SAFARI within GEO is designed to yield a broad range of societal benefits, such as the improvement of management and protection of inland-water, coastal and marine ecosystems and supporting sustainable harvest fisheries and aquaculture programs. SAFARI also aims to help to build capacity at the science and the operational levels, and facilitate the application of rapidly-evolving satellite

technology to address fisheries management questions on a global scale. SAFARI has already conducted a series of activities for promoting remote-sensing applications in fisheries and aquaculture.

So far, two international workshops and one symposium have been organized by SAFARI. The first SAFARI international workshop entitled "International Workshop on the Use of Remotely-Sensed Data as an Aid to Fisheries Research and Fisheries Management" was held at the Bedford Institute of Oceanography, Dartmouth, Canada in March 2008. An outcome of the workshop was the publication of a monograph in the IOCCG Report Series, entitled "Remote Sensing in Fisheries and Aquaculture". The monograph addressed various issues related to fisheries research and management including ecosystem variability and climate change, stock assessment, fish harvesting and marine aquaculture. The second international symposium held in New Caledonia, in 2008, addressed remote-sensing applications in fisheries, adapted to the particular needs and problems of Western and Central Pacific Island countries, for which the report was published in the Proceedings of the SPIE Asia- Pacific Remote Sensing meeting. The first symposium entitled "Remote Sensing and Fisheries" was held at Kochi, India (February 2010) and was organized by Central Institute of Fisheries Technology (CIFT), an institute belonging to ICAR, the Indian Council of Agricultural Research. The symposium focused on a special forum on regional and global applications of remote sensing to fisheries and aquaculture.

Future research in the area of fisheries management will rely heavily on Earth observation data for which, and will exploit improved capabilities of ocean colour sensors, increased spectral resolution, which is essential for identification of phytoplankton functional types as well as improved quantification of chlorophyll and total suspended sediments, differentiation of dissolved organic compounds, monitoring of potentially toxic algal blooms in eutrophic coastal and inland waters, and the estimation of processes such as primary production in inland and coastal waters.

The second symposium on SAFARI (SAFARI-2) is being organized by ICAR-Central Marine Fisheries Research Institute (CMFRI) in January 2018, preceded by a 2 day pre-symposium training. The action items emerging from this symposium will serve to maintain the momentum generated at the Symposium, to advance the science during the inter-session period leading upto the next SAFARI symposium, and undertake follow-up activities emerging from the symposium sessions. The recommendations generated during the deliberations will serve the user communities to exploit satellite remote sensing data for applications related to aquatic ecosystems and fisheries. We recommend that the participants of symposium establish a scientific society with a secretariat for carrying out the action items identifies at the symposium.

Lead Article
Sess: 1a/SI

Marine Spatial Planning (MSP) for sustainable mariculture development

Dineshbabu A. P.
Mangalore Research Centre of ICAR- CMFRI, Mangalore, Karnataka

Indian coastal and marine zone is governed by eight Central Government ministries and similar number of State government agencies. Marine spatial planning (MSP) is recognized as an effective decision making tool for ensuring judicious allocation of natural resources in the marine region among different stakeholders,. "MSP is a public process of analyzing and allocating the spatial and temporal distribution of human activities in marine areas to achieve ecological, economic, and social objectives that are usually specified through a political process". Space technology-based applications like RS and GIS form the basic platform for MSP. In most of the countries MSP is used for allocating space for various activities and developments in the marine sector. MSP is helping in spatial allocation for the Industrial activities, transportation, mining, tourism, natural resource management and fisheries. MSP will help to strike a balance in country's development without hampering the conservation of resources and livelihood of coastal population by providing a desktop solution in planning maritime development activities. MSP in marine fisheries development is still in its infancy in India. In aquaculture, site selection for the identified culture practice is of utmost importance for its success, in which the information on environmental/hydrographical features plays a major role. In aquaculture MSP helps in site selection for aquaculture, for defining aquaculture zones for allocating different aquaculture activities (according to their suitability) and finally evaluating the carrying capacity of each zone to make the aquaculture activities sustainable. India being a beginner in offshore cage farming can learn the lessons from other countries, where aquaculture is in developed stages to expand the technology in extended areas without impacting the environment and without conflict with existing and future probable users of the marine zone.

Site selection for the identified culture practice is of utmost importance for the farming success in which the information on environmental/hydrographical features plays a major role. Satellite information (RS& GIS) based projections are found to be very useful in analyzing each site. It will help to evaluate the introduction of technology in terms of human friendliness as well as eco-friendliness. Area allocated for aquaculture through spatial planning can be further analyzed and may be identified for different aquaculture practices and this is known as aquaculture zoning. Aquaculture zoning will provide policy makers desktop decision making facility for sanctioning the projects and policy decision in mariculture with illustrative map support. Probable impacts of cage installation and cage culture can be projected in spatial platform to arrive at decisions on the carrying capacity of the aquaculture activity. MSP integrates the physical parameters (like current, waves, bottom structure, temperature) chemical parameters (like salinity, DO, BOD,

COD, nutrients, the distribution of the waste, decomposition of waste) and biological parameters (productivity, species suitability and stocking density etc). MSP projections can resolve conflicts for space and resources between stakeholders and also help to understand the social acceptability and economic implications of mariculture. The estimation of carrying capacity will help in suggesting how many numbers of rafts, racks and cages can be put in the particular ecosystem/area without disturbing the natural environment. In case of cage culture the species to be selected, number of cages to be installed, the stocking density and the extent of distribution of waste from cages without causing pollution are the major concern to make the production sustainable. MSP will be crucial for aquaculture development as it lowers the threshold for new entrepreneurs, minimizes the risk of appeals, makes the business more environmentally safe, and lowers the risk of social conflicts.

Indian initiatives of Marine Spatial Planning in coastal aquaculture and mariculture

Maharashtra State has vast stretches of estuaries, creeks and mangrove swamps which have great potential for farming selected finfishes and shellfishes in captivity. The Ministry of Environment and Forests and Climate Change, Government of India, aims to promote mud crab farming in Maharashtra State, considering the vast natural resources like the estuaries, tidal creeks and mangrove swamps. Since the areas are of multi-stake holder usage in nature, multi-criteria analysis in marine spatial planning concept was introduced for the crab culture site selection. This Mangrove cell Maharashtra is carrying out selection of mariculture sites for finfish farming and multi-trophic aquaculture in the mangrove areas of Maharashtra with technical expertise of CMFRI.

An attempt to introduce the micro and macro level spatial planning by using GIS techniques for sustainable use of coastal natural resources for aquaculture was experimented along the coast of Byndoor, Udupi district Karnataka in Sumana–Byndoor River estuary (Fig.). Multi-criteria decision analysis methodology was used for the studies taking into consideration navigational path, water current, water depth, water quality, sediment characteristics, organic load water body for selecting sites for mariculture. The maps for fishing area along the coast, tourism potential of the area, present fishing activity like marine fisheries, estuarine bivalve and crab fishery, use of the water body for navigational purpose, future prospects of crab fattening/crab culture in pens in mangrove area, possibilities of bottom culture of clams in sandy areas, potential seed production and seed nursery facility for finfishes and shellfishes, present areas of prawn farming and areas which can be developed for prawn farming were also indicated. This is the first attempt of spatial planning and aquaculture zoning from Indian waters and the maps helped in deciding the method which can be adopted to extend the mariculture activities possible in specific water bodies with eco-friendly and human friendly concept. The attempt proved that geospatial models are efficient tools for decision support system for monitoring and outlaying any coastal area. These supporting tools will help to plan out the various methods of aquaculture activities in study area, according to the preferences of hydrographic and environmental features existing. Geospatial model

can be developed to balance in a variety of contexts including coastal aquaculture, energy production, natural resources conservation, marine fishing and human recreation activities in coastal area.

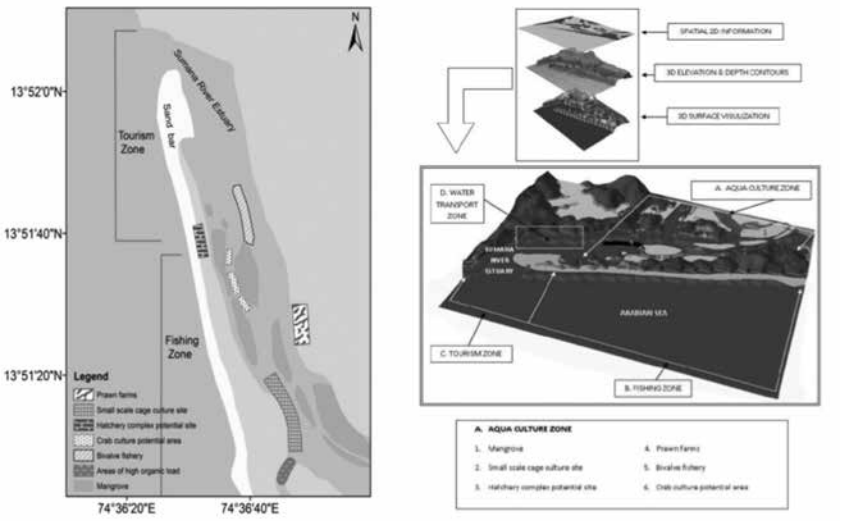

Fig. An example of the micro-level MSP for aquaculture zoning of Sumana river estuary in Karnataka with 3D projection with depth contours of the estuary.

Lead Article
Sess: 1b/BD

Biodiversity – a depletable product of organic evolution!

Menon N. R.

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Biological diversity is the natural stock of genetic material in an ecosystem. The stock may be determined by the actual number of genes existing within the system. The number of genes between organisms range from about 1000 in bacteria to 10,000 in fungi to around 100,000 in a typical mammal. The greatest number of genes actually belong to the flowering plants- around 400,000 or more! genes decide the real character of a particular organism. They are coded with information which determines the specific capabilities of a given organism. The greater the variety in the gene pool, the greater is the variety of organism. The usual tool employed for the analysis of biological diversity is the number of species that exist. Actually this is the net result of the processes of speciation and extinction. We all know that the number of species that exist far exceeds the number of species so far described. The diversity of species has resulted from "radiation", a process that has occurred over many hundreds of millions of years. It is certain that this process was never a continuous one. Records collected from the palaeoecology of the biological system shows that we have around 4.5 billion years of 'biological history'. However, the first four billion years found the existence of single celled blue green algae and very simple multicellular organisms. "Adaptive radiation" as a matter of fact was crawling for 4 billion years. It is certain that some unknown event triggered adaptive radiation. The Paleozoic era saw the rush of speciation. All the major phyla appeared in a matter of short period extending to around one hundred million years. The size and range of biodiversity resource was decided and determined by this organic revolution.

Extinction, a function which decides biodiversity depends on the longevity of any species and the time period for this could range from 1 to 10 million years. The threat to biological diversity arises when the rate of extinction of species far exceeds the rate of speciation.

The diversity of biological resources is a one-time endowment from the evolutionary process. Although individual biological organisms may be treated as renewable resources, the aggregation of differences between these resources i.e. the diversity that they represent, is best conceptualised as a non-renewable resource. Biodiversity is the actual natural resource which exists at the interface between the spheres of renewable and non-renewable resources. In biological diversity we are dealing with one of the ancient non-renewable resources, such as the fossil fuels, rich soils and great aquifers, although in one respect biological diversity is different from other non-renewable resources.

The value of biodiversity lies in the fact that evolution has produced the present range of 'variety'. Evolution has a built in capacity for adaptation, and therefore the variety that exists as we see today. We should realise that the existing life forms encapsulate a history of successful adaptation within a changing environment. It is not possible to substitute human- synthesised inputs or processes for the important characteristics of biodiversity. There is no artificially created substitute for the half-billion years' experience that biodiversity represents. Biodiversity management concerns the management of the unique characteristics of the one-time endowment from the evolutionary process.

The problem of global biodiversity losses derives from the failure to consider the impacts upon global stocks when taking regulation decisions. The biological diversity problem is infact the predictable result of an imperfection in the global regulatory system with regard to diverse resources. Decentralised decisions regarding diverse resources cannot take into account the innate value the diversity of such resources.

Keynote
Sess: 3/SE

Communication technologies in early warning of coastal disasters driven by oceanogenic and meteorological forces

Antony Joseph
Formerly Chief Scientist, Marine Instrumentation Division, CSIR-National Institute of Oceanography Goa, India

Categories of coastal disasters

Two major categories of oceanogenic and meteorological disasters often times experienced in coastal regions are tsunamis and storm surges. Indian coastal and island regions are vulnerable to both of these disasters. Many lives can be saved if timely early warnings can reach the coastal people (locals, and visitors of national and foreign origin) through effective communication technologies.

Requirements for risk mitigation

Requirements for risk mitigation include (i) Availability of information on risk factors in real/near-real time, and (ii) Near-real time dissemination of risk information to "Disaster Management Centers" and the Public.

Modes of data reporting

Different modes of data reporting are used in different parts of the world. These include: (1) Wired telephone connection, (2) VHF/UHF transceivers, (3) Satellite transmit terminals, and (4) Cellular connectivity.

Advantages and limitations of various data reporting systems

The data reporting systems mentioned above have their own inherent advantages and limitations. For example, wired systems are susceptible to connectivity loss during natural disasters (trees falling on telephone lines; wind uprooting telephone poles, etc). VHF/UHF systems suffer from limited range. Satellite based systems have the advantage of global coverage, but such systems are expensive & high logistics are required. Cellular systems have the advantage of being affordable, and provide wide coverage. Furthermore, cellular systems have low initial & recurring costs.

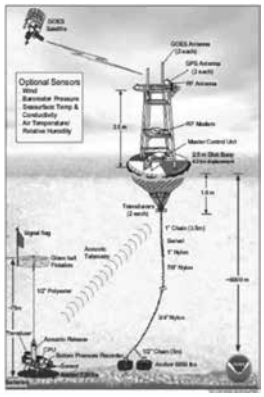
Typical examples of data communication methodologies currently in operation

1. Sea level network in UK communicates sea level data to a Central Station via Wired telephone connection.

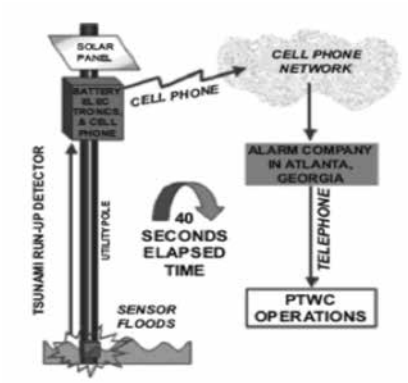
2. Open ocean moored buoy system — known as DART — consisting of a seafloor bottom pressure recorder and a surface buoy that receives the bottom pressure, communicates seafloor bottom pressure data string in real-time via satellite.

3. Tsunami run-up detectors used by Pacific Tsunami Warning Center, based on home security alarm technology, communicate data via cell phone.

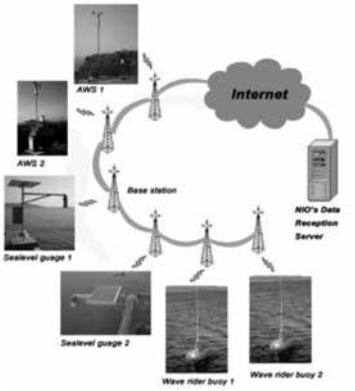
4. CSIR-NIO's in-house designed network of Internet-accessible real-time reporting sea-level, sea-state and surface meteorological stations communicate data via cellular network.



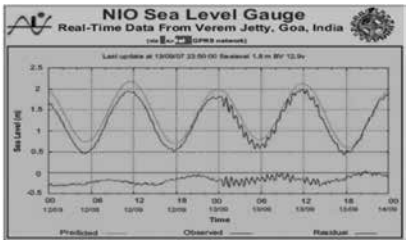
DART communicating seafloor bottom pressure data string in real-time via satellite.



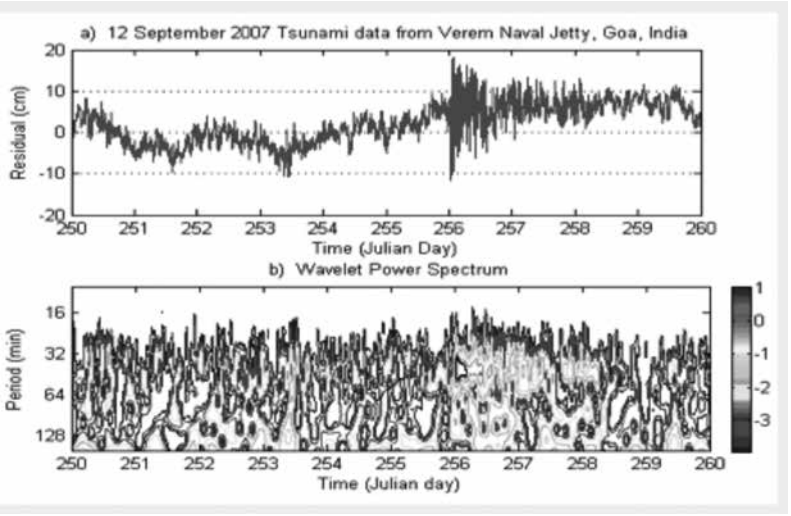
Tsunami run-up detectors used by Pacific Tsunami Warning Center communicating data via cell phone



Block schematic of CSIR-NIO's network of Internet-accessible real-time reporting stations communicating multiple parameters via cellular network.



Internet-accessible, real-time graphical reporting of September 2007 Sumatra tsunami arrival at Goa through CSIR-NIO's cellular network of radar-based sea-level gauges.



De-tided sea-level and wavelet power spectrum of the real-time-reported September-2007 tsunami at Goa

Keynote
Sess: 4/AQ

Applications of remote sensing for sustainable development of aquaculture

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The present global production of food fish is around 167 million tonnes from capture and culture. Demand for fish has increased at twice population growth over last 50 years. Estimated additional 20-30 million tonnes are required to meet the demand by 2020 which could even be an underestimate. Percapita consumption of fish has increased from 11.5kg in 1970 to 12.5kg in 1980 to 14.4kg in 1990 to 20.0 kg in 2014. It is generally well accepted that aquaculture is the only way forward to meet the additional requirement of fish in future years. Aquaculture is the fastest growing food production sector with an annual average growth of >6% in the last two decades. It increased from <1 million tonne in 1950 to 73.8 million tonnes in 2014 and is still showing a steady increasing trend. . It is projected that In India we need to produce about 18 million tonnes of fish by 2030, as compared to 10 million tonnes we produce today. In this case, we need an additional production of 8 million tonnes in the next 12-13 years and we have to focus on aquaculture for meeting the increased demand of fish in future years. It is inevitable that sustainable aquaculture production to meet the increasing demand for fish protein has to be given topmost priority in the immediate future. In this regard, an Ecosystem Approach to Aquaculture (EAA) which involves all the stakeholders to ensure ecological, social and economic sustainability, thus assuring the farmers their immediate and future livelihood option can be the right track that can be followed. Remote sensing provides several essential elements to support the implementation of EAA. Hence, it is very timely to examine how the application of Satellite Remote Sensing (SRS) data and also integration of the same with Geographical Information Systems (GIS) can play a vital role in attaining sustainable aquaculture production.

The main issues addressed by remote sensing in aquaculture development are (i) strategic planning and development at global and regional levels (ii) suitability of site and zoning and (iii) regular monitoring and management of aquaculture practises. The planning and implementation of EAA require spatial information about ecosystem components, and advances in remote sensing have enabled us to plan aquaculture development, support environmental impact assessments and monitoring. Planning for aquaculture development also requires understanding of the environment and assessing the suitability of a given region for a particular project to be sustainable. For example, in the assessment of mariculture potential of a region it is needed to consider environments suitable for the culture systems (eg. depths, current speeds etc. for cages), environments that favour fast grow out of cultured organisms (eg. water temperature, food availability

as chlorophyll a for filter feeders), distance from shore to culture site and conflicting/ complementary uses of the area.

The majority of problems currently faced in aquaculture lie in the spatial domain and is the key to success or failure of aquaculture production. The factors such as quality and quantity of water, the water temperature, productivity of the aquaculture site is of prime concern. Strategic planning at global and regional levels for development deals with data at a relatively low resolution using a few key data sets to generate indicative results of aquaculture potential. Zoning or aquaculture site selection is the process of identifying and characterising the most promising sites for aquaculture. The zoning and site selection process requires a range of different data, for eg. in sea cage farming, parameters such as water currents, winds, wave height, and depth have to be assessed. Environmental factors such as water temperature, primary production, turbidity, salinity and dissolved oxygen which promote the steady growth of cultured organism have to be evaluated at the culture site. In addition, information on socio-economic, political, legal and planning data are also very significant. The process may begin by considering a larger area and systematically narrowing down the options into zones on the basis of different parameters and ending finally to a smaller area for a detailed study. Hence suitability of a site or zoning require progressively more detailed data at higher resolutions and analysis should provide relatively higher accuracy of results. Eventhough several water quality and physical properties of water bodies of interest to aquaculture can be assessed by remote sensing, the limitation is that remote sensing can meet only part of the information needs and some of the important suitability criteria such as dissolved oxygen cannot be determined by remote sensing data and data such as salinity, ocean colour and currents may not be provided at sufficient temporal and spatial resolution from satellite remote sensing in coastal areas. Surveys in the areas have to be undertaken to mitigate this issue of spatial resolution.

Maximising the spatial equilibrium with all factors in a stable balance is of vital concern which necessitates performing of spatial analysis by employing GIS tools. Satellite and aerial remotely sensed data and information provide the largest source of data and of locational accuracy to GIS. Satellite remote sensing in particular provides a unique capacity for regular repeated observations of the entire globe or specific regions at different spatial scales. GIS are computer based systems whose incorporated software are capable of using geo –referenced data for a range of spatial analysis and outputs. GIS add value to spatial data by allowing the data to be organised and viewed efficiently, by integrating them with other data , by analysis and by the creation of new data that can be operated on and thus creates useful data to help decision making. In the marine context, Marine Spatial Planning (MSP) is a tool in this regard , for eg. in the site selection for cage farming. The MSP provides a step by step approach to balance the uses and users of the marine environment with a view of providing a co-ordinated system that results in the development of a marine spatial plan. It assists the strategic planning for regulation, zoning, management , protection and sustainability of the marine environment.

It is well understood that sustainable aquaculture is targeted at achieving long term

optimum production by maintaining a green environment. The main applications of remote sensing in aquaculture practice and management in this regard are (i) inventory and monitoring of aquaculture and environment and (ii) environmental impacts of aquaculture. Many of the environmental factors that influence the sustainable development of aquaculture in seas or inland waters can be measured by satellite remote sensing. The carrying capacity assessments of the culture environment are essential before any species is farmed either in the sea or freshwater ecosystems. When the organisms are cultured on the food available in situ as in the case of filter feeding bivalves, the carrying capacity of the environment is of vital concern and the same can be accessed by remote sensing through the calculation of phytoplankton production. In the case of cage farming since the food is provided to the cultured organisms, the factors influencing carrying capacity include the total number of cages in a given area, stocking density of fish per cage and feeding intensities. Unutilized feed and metabolic waste disposal is a function of local residence time which is determined by factors such as tides and currents. Harmful Algal Blooms and severe weather conditions are perennial threats to aquaculture. Avoiding toxic phytoplankton needs analysis of spatial distribution of toxic blooms. Protection from severe weather conditions requires analysis of local topography in the context of the prevailing wind and wave fields, as well as vulnerability to extreme events such as cyclones. From the above, it is evident that the SRS in conjunction with GIS can be applied to combat the risks arising from severe weather conditions, harmful algal blooms and accumulation of waste products of metabolism.

Remote sensing provides the aquaculture management agencies /regulatory authorities with capacities to regularly monitor the extend of aquaculture development and to check if it is proceeding according to marine spatial planning / or regulations or if it is not adversely affecting the environment. The near real time delivery of data and its integration with in situ data and models for monitoring the environment can provide timely information and even forecasts that are useful in aquaculture management. In addition, the use of remote sensing integrated with GIS could be of immense value in developing or enhancing environmental impact assessment (EIA) related studies for assessing the potential impacts of aquaculture on coastal environments. Advances in remote sensing systems, communications technology and computer processing have made remote sensing data more accessible and these facilities have accelerated their aquaculture applications. Many obstacles that had once hindered the application of remote sensing are now less problematic, including affordability, information content, timeliness and delivery frequency. The unique capability of satellite remote sensing to provide regular, repeated observations of the entire globe or specific regions at different spatial scales will also become increasingly important in the context of global climate change and the EAA. It can thus be concluded that remote sensing integrated with GIS can play a vital role in the future development of EAA. Eventhough these technologies are mainly associated with developed countries, extreme flexibility of GIS with regard to its sophistication, developing countries also will have many options to benefit from the systems that are designed to match their needs or capacities.

Lead Article
Sess: 4/AQ

Sustainable use of natural resources for brackishwater aquaculture in India using remote sensing and GIS technologies

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Brackishwater aquaculture, which convert waste lands to wealthy ones by culturing shell fishes and finfishes under controlled environmental conditions can immensely contribute to the socio economic growth of the coastal livelihoods. Globally aquaculture is one of the fastest growing food sector since 1970s, but confronted with many environmental issues due to unplanned, improper use of resources and unregulated growth of the sector. Conversion of mangroves and productive agricultural lands, salinization of agricultural lands and drinking water resources, multi user conflicts have created concern on the impact of aquaculture development on environment and raised the question about its sustainable use of resources. Studies have indicated that aquaculture was the most frequent cause of anthropogenic change for the mangrove loss in shrimp growing south east Asian countries. Hence, sustainable use of natural resources for aquaculture is one of the most crucial issue in the coastal countries.

As India is bestowed with 3.5 million ha of brackishwater area due to the confluences of sea and river water in estuarine zone spread across the nine coastal states and four territories, aquaculture using bracksihwater can play a significant role for food, employment and prosperity. But the unregulated and uncontrolled growth of aquaculture in the country since 1987, has brought the sector under regulatory regime with licensing guidelines in 1996 through establishment of Coastal Aquaculture Authority. Comprehensive planning for the aquaculture is still uncommon and the facts that many farms are abandoned or are suffering from significant disease problems in spite of only 14 % of resources use in the country demonstrate the need for such improvement in planning and management. To develop aquaculture with long term sustainability and social acceptance, planning is essential with incorporating ecologically important ecosystems presence and other coastal resource use in an environmentally-integrated mode. In addition, aquaculture development is faced with several challenges due to global warming with increasing extreme events such as floods, cyclones, drought, tsunami and vulnerable to climate change as it depends on land and water resources completely.

Satellite images are increasingly utilized as data sources in conjunction with geographical information system (GIS) in decision making process which involves multiple criteria ranging from local to global level decision making with present, past and future scenario. Satellite data products are available with different temporal and spatial resolution and

to cater the needs of different applications and user requirements in aquaculture. The data resolution can be need-based and vary from sub meter high resolution to 120 m low resolution for the planning of aquaculture. The selection of satellite data depends on objectives of the study, spatial extent of the study area, frequency of time series data requirement, information to be derived, facilities available, additional data to be linked and the budget. Many commercial and open source image processing and GIS software's are available for decision making in relation to aquaculture. It is mostly used for optimizing site selection, impact assessment, monitoring development either in combination with remote sensing or alone of aquaculture. Every GIS software has got its own functional capability to perform the range of functions to support different decision making processes.

Comprehensive planning with identification of sites suitable for aquaculture based on multiple criteria such as land use pattern, water quality, water availability, soil characteristics, neighbouring land use, restricting regulations, buffer zone need to be done at state or national level along with species suitability and diversity. Carrying capacity of source water bodies and ecologically important ecosystems presence need to be analysed prior to planning the development of aquaculture. Climate change is expected to bring more challenges on the coast such as increasing frequency and intensity of floods and cyclones, sea level rise and inundation of resources, that can result in loss of ecosystems and change in distribution and abundance of fish stocks. Saline water intrusion in the coastal region will make agriculture lands unfit for crop production, where brackishwater aquaculture can play alternative livelihood support. Identifying, planning and proper use of brackishwater resources will pave the way for economic development in one hand and sustain the use of land and water resources in other hand. For this, integrating and linking all the institutions working using spatial data for the coastal development will help in conservation and sustainable use of coastal resources.

Lead Article
Sess: 5/HF

Application of remote sensing in Harvest Fisheries

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More than 200 million people around the world depend directly on fishing for their livelihood and as their major source of protein and, employment. Asia contributed 75% of the total fishing vessels in the world out of which 64% are engine powered and fossil fuel driven. India with a coastline of 8118 km , occupies third rank in world marine fish production and the fisheries sector contributes 4.47% to the agriculture GDP. The country has four million fishers, who are directly dependent on fishing for livelihood. India has about 140000 vessels, which are engine powered, and use fossil fuel as the energy source and contributing more than 90% of the total catches of the country. The diesel consumption by the mechanized and motorised fishing vessels in India is estimated at 1378.8 million litres in 2010, which releases about 3.13 million tonnes of CO2 to the atmosphere at an average rate of 1.02 tonnes per tonne of live-weight of marine fish landed. The dependence on fossil fuels, have negative connotations with regard to energy use and delirious impacts due to emissions, when compared to other methods of food production. Any intervention towards reducing the consumption of fuel will positively affect the resources and also the economics of the small scale fishing vessels operating in the country.

Fisheries is a very complex subject and it depends on the interplay of different factors which are often intricately associated. Most of the studies on fisheries management and harvest technology carried out in India and elsewhere, are based on "point" observations, by sampling from specified location. These studies have the drawback of the lack of a synergetic approach and hence often fail to associate the inter-connections existing in the ecosystem. Remote sensing has enabled scientists to study the earth's biotic and abiotic components on a very large scale. These components and their changes are being mapped from space at several temporal and spatial scales, which makes the studies of fish and its interdependence to the biotic and abiotic factors, very economical and with considerable reduction in time. Variations in environmental conditions affect the recruitment, distribution, abundance, and availability of fishery resources. It is not possible to measure remotely from satellites the entire spectrum of information needed to asses changes in the marine environment. However, Knowledge of important oceanographic conditions and processes affecting fish populations may often be deduced using ocean measurements made by satellite. e.g. distribution of surface isotherms, locations of oceanic frontal boundaries, information on currents and circulation patterns, regions of upwelling and so on. Since variations in the ocean conditions play a very important role in natural fluctuations of fish stocks and in their vulnerability to harvesting, timely information on these conditions will be great help for the fishers, researchers and the

policy makers alike. The evolving capabilities of satellite sensor and data-processing technology, combined with conventional data collection techniques, provide a powerful tool towards information on the location of the fishery resources indirectly by collecting and processing information on the causal factors.

One of the most successful application of remote sensing technology in the harvest fisheries in India has been the development of Potential Fishing Zone (PFZ) advisories that have proved to reduce the scouting time, fuel cost and concurrently increasing profits for the small scale fishers of the country. The technology involves the gathering of ocean colour, sea surface temperature and the winds data from satellites and identifying the features from the merged images. Features like eddies, rings, meanders, thermal fonts, upwelling regions etc. are identified and the probable locations of fish aggregations are forecasted. The technology developed by Space Applications Centre (SAC) was later taken up and upgraded by the Indian National Centre for Ocean Information Services (INCOIS) into an operational forecast on a regular basis for the entire coast of India called Marine Fishery Advisory Service (MFAS). The product supplied to the fishers include the position of the PFZ, distance of the PFZ from the landing centre and bathmetry. It also includes the mixed layer depth, current and wind directions and the information of high wind-waves. The dissemination is by different methods to reach the stakeholders in time so that the information could be used effectively.

ICAR-CIFT has been involved in the experiments for PFZ from the development stage of the technology with SAC and validation of the MFAS generated by the INCOIS along Gujarat coast. Studies conducted by ICAR-CIFT has shown that in purse seining maximum fuel is spent in searching for the shoal. Studies on the validation of PFZ along Gujarat coast showed an increase in the CPUE of multi day trawlers by 20-30%. The accuracy of the estimates was around 40% in case of bottom fishes, which were validated using Departmental fishing vessels. The diesel savings in case of multi-day trawlers operating along Gujarat coast were found to be between 100-150 litres, when compared to vessels not using PFZ information. Significant improvement in the cost-benefit ratio was also notices, when using PFZ information by the fisheries. The mean C/B ratio increased by 20-50% in case of multi-day trawlers. In ring seine fisheries more than 70% of the operational expenditure is for fuel as ascertained from the studies conducted on ring seine fishing vessels operated from Cochin area. PFZ information is also found to significantly reduce the time required for scouting and also an increase in the CPUE by 2.3 times along Goa and Kerala coast is reported. The accuracy of the forecasts for the demersal resources targeted by trawls were found to be between 40-50%, which is less when compared to the pelagic resources. The problem with regard to cloud cover and non-availability of satellite data often exists in the southern states, but the effective use of GIS has the potential to overcome two long-standing problems associated with satellite-directed fisheries: 1) the absence of information due to clouds; and 2) the general lack of support for nonpelagic fisheries. Attempts are already been made by INCOIS by involving GIS techniques for the developing PFZs for non-data days, which will improve with more background observation in time.

INCOIS is also disseminating tuna forecasts since November 2010, by perfecting the

technology using hind-cast experiments. Since the studies related to tuna are coupled with satellite/acoustic telemetry, an end product with very high accuracy is expected in the near future, which will boost the tuna fishing industry, which is waiting for a big leap in the Indian scenario. Species-specific forecasts are also tried by ICAR-CIFT with the collaboration of INCOIS on the prediction of Acetes sp., which is often considered as a keystone species along the northwest coast of India. Significant association and quantification of the abundance of Acetes with chlorophyll, sea surface temperate and nitrate were derived as part of the project. This model can be an input for developing species-specific forecasts along the coast, since the abundance of Acetes is very closely linked to major commercial species like ribbonfish and squids along the Gujarat coast.

The catches from the Indian marine fishery has been stagnating for a decade now which is mostly due to the unbridled increase in the capacity and the effort that has been pumped in. Most of the resources are now exploited to the maximum and severe restrictions both with regard to seasonal and temporal approaches are warranted. Remote sensing with its capabilities can easily identify areas of ecological importance and hence such areas can be marked, which can be set as marine reserves or no-take zones. Attempts towards this should be taken up urgently.

There are also problems with regard to the capture of threatened species like turtles, whale sharks, dugongs etc. that required urgent remediation. The interventions can CIFT-TED can be effectively used in trawlers along the east coast of India, if real time information regarding the paths of turtle migrations is available. The accidental capture and subsequent deaths can be considerably reduced if methods employing remote sensing like TURTLEWATCH used in the US and other countries are available for the Indian seas.

ICAR-CIFT is also involved in refining the algorithms available for the case-2 waters. Inherent optical properties of sea water in the coastal regions are being collected regularly and analyzed and feedback given to INCOIS for refining the algorithms. These efforts by INCOIS will further help in the quantification of the causal factors for fish abundance and will significantly improve the prediction capabilities of the models.

Remote sensing with its inherent capabilities can contribute significantly in fish harvest and the results are very encouraging in the Indian scenario. The main advantage in the fishing sector is the reduction in the scouting time and concurrent decrease in the fuel consumption. Since energy is the buzz word now, the main role of remote sensing technologies in fishing would be by making fishing more green by reducing emissions. Since the marine resources are on a declining trend, efforts towards using these technologies for conservation along the coastal waters need to be escalated.

Lead Article
Sess: 6/FM

Fisheries & remote sensing

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At the dawn of the 20th century, fisheries science, as exemplified by the landmark monograph of Hjort (1914), was based on the view that it should develop in a whole-ecosystem context. The ecology of larval fish was considered to be of paramount importance. Laudable though this thinking was, it proved to be difficult and costly to implement at the appropriate scales of time and space using field measurements. Instead, there developed the view, embodied in the work of Beverton and Holt (1957), that fish population dynamics could be described by equations with a small number of parameters, and from which explicit reference to the ecosystem was lacking.

But it came gradually to be realized that such an approach was not supplying adequate advice to those charged with the responsibility for maintaining the sustainability of exploited stocks. Major fisheries collapsed, with massive damage to the social fabric of fishing communities. Even Beverton (1998) acknowledged that use of population dynamics from which ecosystem properties were excluded was too austere, and that inclusion of explicit reference to inter-annual fluctuations in environmental and ecological factors would lead to more robust advice for fishery managers. In other words, the pendulum was swinging back to the vision articulated by Hjort (1914) almost one hundred years earlier.

But meanwhile the technical context had changed. Whereas earlier, the implementation of an ecosystem-based population dynamics had been constrained on grounds of expense and the difficulty with matching observations to the relevant time and space scales, the advent of remotely-sensed observations from instruments carried on spacecraft in Earth orbit now provided time-series data on physical properties, such as sea surface temperature, and biological properties, such as concentration of chlorophyll, cell size and functional types of phytoplankton. These data streams met the desired characteristics of precision, spatial and temporal resolution, as well as cost-effectiveness (Platt & Sathyendranath 2008). Ecosystem-based population dynamics of fish could now begin.

Various approaches were possible to achieve this goal. For example, Platt & Sathyendranath (1996) proposed that interannual fluctuations in the characteristics of the seasonality (phenology) of the pelagic ecosystem be quantified by analysis of the chlorophyll time series. In other words, treating the seasonality as a wave, the idea was to extract the phase of the wave in each year for which data were available. A climatology of ecosystem phenology could be built over the years, and events occurring in particular years in the population dynamics of fish populations of interest be compared with anomalies in the same year against the climatology. Such an approach enabled

Platt et al. (2003) to make the first operational test of the Cushing-Hjort hypothesis (Cushing 1990) on the relation between synchrony (or otherwise) in timing of spawning and anomalies in the phase of the phytoplankton in the same year. It was possible to show, for a demersal fish the haddock (Melanogrammus aeglefinus) on the coast of Nova Scotia (Canada), that early spring blooms of phytoplankton were conducive to greater larval recruitment in the same year. Such a finding is clearly of high value for those charged with explaining the fluctuations between years in the abundance of the target fish species.

Other examples followed, such as the northern shrimp, Pandalus borealis (Koeller et al. 2007; Fuentes-Yaco et al. 2007; Koeller et al. 2009), cod, Gadus morhua (Trzcinski et al. 2013), and description of the ecosystem (Platt et al., 2010; Zhai et al. 2011). Among these, Koeller et al. (2009) is remarkable in that it demonstrates robust relations between shrimp biology and environment at the full sweep of the north Atlantic basin from east to west and from 40 to 800N. Platt et al. (2007) provided a retrospective.

The success of these early attempts to incorporate remote sensing into fishery science spurred the establishment of the SAFARI programme (Societal Applications in Fisheries and Aquaculture using Remotely-sensed Imagery) with support from the Canadian Space Agency. One important activity was to convene the first international symposium on remote sensing and fisheries, in Cochin, India, in 2010, hosted by Central Institute of Fisheries Technology (an organ of the Indian Council of Agricultural Research, ICAR) under the leadership of Dr. B. Meenakumari. The symposium led to publication of an entire issue of the ICES Journal of Marine Science, (see Stuart et al. 2011) for the Introduction to the special issue). Another significant activity was the publication of a monograph in the International Ocean Colour Coordinating Group series (Forget, Platt & Stuart eds., 2009) as a background to the first Cochin symposium.

Clearly, the first SAFARI symposium was an important catalyst in the development of remote-sensing applications in fisheries ecology. The participants at the first symposium were unanimous in requesting that SAFARI symposia be held on a regular basis, as a venue for bringing together fisheries and remote sensing scientists. After a gap of some eight years (a gap that is longer than ideal), the second SAFARI Symposium is now being held, hosted by Central Marine Fisheries Research Institute (CMFRI), another ICAR organ, under the leadership of Dr. A. Gopalakrishnan. It is fitting then, that the second international symposium on remote sensing applications in fisheries also be held in Cochin, and we can expect with confidence that it will provide another major stimulus to progress in this field. We hope that the second symposium would lead to the establishment of a permanent SAFARI Secretariat, which would foster the communications in the field post symposium, and help organize the next one. We trust that one would not have to wait another eight years for the third SAFARI Symposium.

Every major international event of this type has unsung heroes in the background, who have worked tirelessly for its success. It would be fitting to highlight at least two of them for special mention: Dr. Grinson George and Dr. Nandini Menon, who have worked day and night to bring the symposium to fruition. No detail has been too small

for their attention.

We felicitate the leadership at CMFRI and all sponsors, national and international, for organizing this event, which is a landmark for those working in the fields of remote sensing and fisheries.

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Lead Article
Sess: 5/HF

Application of remote sensing in harvesting fisheries through Potential Fishing Zones (PFZ) - the Andaman experience

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The oceanic islands of the Andaman and Nicobar (ANI) forms the largest archipelago in the Bay of Bengal comprising 572 islands, islets and rocky outcrops (ANDFISH 2005). The marine fish production in the ANI is about 38,000 tons out of 1.48 lakh tonnes. Potential fishing zones were seen as an important tool for enhancing fish catches through guided fishing. Their efficacy in the Andaman and Nicobar Islands were evaluated through various dissemination modes and further research on using sea surface height (eddies) to improve and augment the PFZ advisories were taken as principal research component for use in Andaman and Nicobar islands. The study has yielded significant observations on mesoscale eddy in Islands and their potential to predict PFZ. Remote sensing data detects the fishing grounds based on remotely sensed sea surface temperature and chlorophyll which makes a conducive environment for feeding habitat for marine fishes. Guided fishing is very relevant since ANI is currently exploiting only 30% of their estimated potential of 1.48 lakh tonnes and hence suitable technologies are to be developed to harvest the fishes in a sustainable manner for livelihood and entrepreneurship development in the Islands. Moreover guided fishing

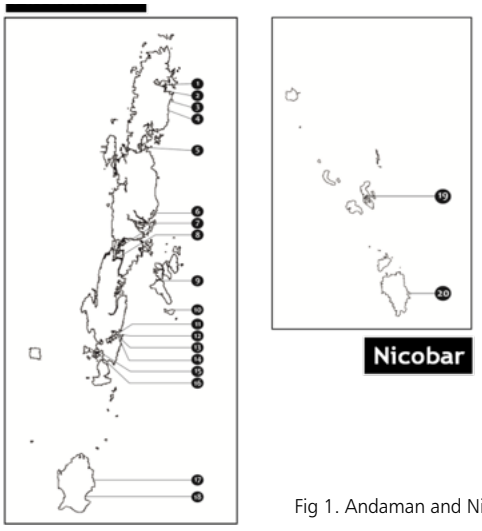


Fig 1. Andaman and Nicobar group of Islands

with coordinates and depth makes the work convenient and saves fuel and time leading to more economic returns. The PFZ advisories were disseminated through Electronic display board, SMS, email, phone calls and maps. 20 landing centers in Andaman and Nicobar Islands covering all the districts including North and Middle, South Andaman and Nicobar group of Islands (Fig 1)

Salient observations of the study

- 34% increase in mean catch per unit effort of fish catch among PFZ users
- 51% reduction in the time taken to locate fishing grounds
- 43% of PFZ forecasts were validated.
- 46 awareness campaigns and 600 fishermen were sensitized and benefitted through the study

The technology disseminated has a wide impact on Island fishermen as the benefits were conceived and received well. Remotely located Nicobar region Campbell Bay has maximum adoption rate (83.3%) during the study followed by Diglipur (58.3%) in North Andaman followed by Rangat (52%) in Middle Andaman and Junghlighat (41.1%) in Port Blair as shown in Table .1

Table 1. Adoption rate of PFZ technology among ANI users

Fish landing centre	Total number of fishers	Number of PFZ users	Percent (%)
Diglipur	300	175	58.3
Mayabunder	245	60	24.4
Rangat Bay	400	210	52.0
Guptapara	100	22	22.0
Junglighat	850	350	41.1
Wandoor	160	35	21.8
Hut Bay	200	75	37.5
Nancowrie	150	30	20.0
Campbell Bay	300	250	83.3

Prior to PFZ there were no any specific technologies validated in the Islands which augmented the fish catches and hence the initiative was appreciated and widely used by the fishermen. Guided fishing makes fishing more convenient with efficient utilization of time and fuel leading to enhanced benefits and crew safety. The validation of PFZ forecast was done visiting the landing centres, the summary of the observations are as follows:

Seventeen fish landing centers were identified in Andaman Islands during the period of July 2013- June 2014. A total of 312 visits were carried out during the period and the maximum visits (172) were carried out at Junglighat fish landing centre. Altogether 1,920 operations of boats were carried out from all landing centres during period. The

total fish landing and the average monthly landing were 7,33,385 kg and 61,049 ± 9,647kg respectively. More than 10 types of fishing gears were engaged from all landing centres, out of which catch from ring net was more than 51 % of total catch. Altogether 337 operations of ring net were carried out during the year (monthly average of 28.1 ± 5.3). Similarly total catch from ring net was 3,77,540 kg (monthly average 31462 ± 5,797 kg). The major fish catch of ring nets were Mackerel, followed by Sardine and small Carangids (Atule sp., Decapterus spp., Selar spp., and Megalaspis sp). Altogether 297 Gill (Drift) net operations were carried out. Total catch from gill (Drift) nets was 71,063 kg (monthly average of 5,922 ± 1,317 kg). The major fish catch of gill (Drift) nets were Tuna followed by Scombrids, Barracuda, Carangids, Shark and Marlin. Altogether 423 operations of other gill nets were conducted during the year. Total landing from other gill nets was 12,675 kg with a monthly average 1,056 ± 278 kg respectively. The major landings were Sardines, Mackerels, Anchovies, Silver bellies, Carangids, Barracudas, Groupers, Snappers, Mullets, Shark and Sting rays. Altogether 61 operations of Trawl nets were conducted by trawlers from Junglighat fish landing centre and their average landing was 6,747 ± 1541 kg/month. The major fishes caught by trawl nets were Silver bellies, Carangids, Serranids, Lutjanids, Thunnids, benthic fishes, Mullets, Carcharhinids, Mylobatids, flat fishes, barracuda, prawns, cuttle fishes, Shark and Sting rays. In total 212 Long line operations were carried out and their average catch was 6,246 ± 1,193 kg/month. Altogether 572 operations of hand line were carried out with an average catch of 9,534 ± 2,582kg/month. The major landings of Long and hand lines were Serranids, Lutjanids and Lethrinids. The average catches of gears such as Disco net, Anchor net, Shore seine and Harpoon were 177.5 kg, 7.3 kg, 22 kg and 110 kg per boat respectively and the landings constituted mostly prawn, silver bellies, carangids, groupers etc (Dam Roy et.al 2014)

Though the technology has wide range of applicability in the Islands, they have some limitations as follows:

Major limitation of the study (Conventional PFZ)

- Remote sensing data is highly influenced by cloud cover and rainfall
- The sensors won't detect the fishing grounds due to adverse weather
- ANI is complimented by both southwest and northeast monsoon (June-Dec) with a brief break between monsoons
- This limitation makes issues with respect to round the year PFZ advisories and hence makes advisories seasonal only

Further studies to generate round the year PFZ advisories

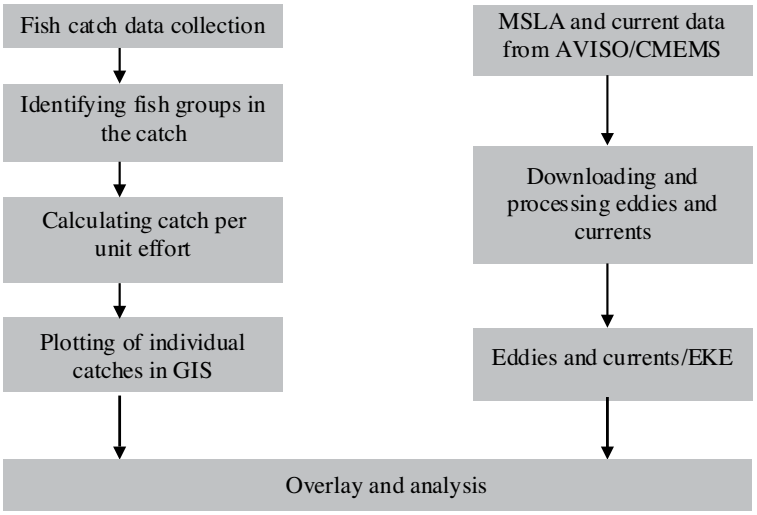
Mesoscale eddies are very prevalent in the vicinity of ANI (Arur 2014) and will be spread over span of months and could be an excellent tool for PFZ. SARAL ALTICA space satellite detects the changes in sea surface height in (mm) which is made use to detect the eddies

and the upwelling /downwelling areas.

Major steps involved in the study

The study involves collection of fish landing data from the landing centers of ANI with details on fish groups (pelagic, demersal and oceanic) species and catch-effort data. Simultaneously mean sea level anomaly maps are used to detect the eddies, upwelling-downwelling regions and plotting the fish catch for analysing the link between eddy occurrences, fish catches and catch –effort data to understand the productivity of the eddies in ANI. The process is again illustrated in Fig. 2.

Fig 2. Schematic representation of the work link and correlating eddies with fish catch



Significant observations

1. Around 114 traditional productive fishing grounds of various gears were documented from the study.

2. Positive relationship of Eddies with fish catch has been established through 3 years of catch data post-analysed with SLA Generated Advisories and validation results corroborated with the findings from historical catch

3. Conventional fishing grounds profiled (gear-wise and season-wise): There is scope for expanding fish catch, as most of current catch come from non-eddy areas.

For the first time sea surface height (eddy) based PFZ advisories were generated and validated in ANI for experimental purposes. A typical eddy advisory generated is given in Fig 3

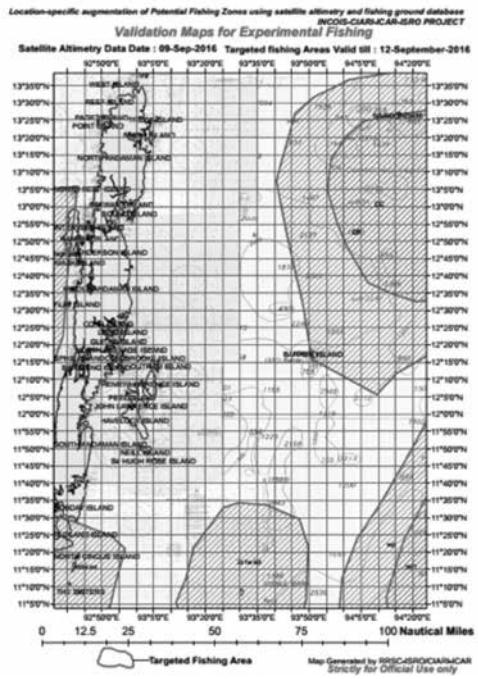


Fig 3. Eddy based PFZ generated for experimental fishing in ANI

Potential fishing zones were seen as an important technology which could suitably enhance the marine fish landings in ANI. Guided fishing is a convenient form for fishermen venturing in sea to save fuel and time. The Potential Fishing Zone forecasts based on chlorophyll and SST maps retrieved from ocean colour and thermal imagery disseminated by the Indian National Centre for Ocean Information Services (INCOIS) have been proven beneficial to the fishermen of the Islands (Grinson et al. 2011, 2013). However, Andaman and Nicobar Islands are under cloud cover for about eight months of the year, which obscures optical and thermal imagery and hinders the generation of PFZ advisories (Grinson et al. 2014). The all-weather capability of altimeter data, and their ability to identify mesoscale eddies and established relationships between eddies and fisheries in ANI could be beneficial in generating eddy based PFZ advisories. Such remote sensing advances could lead to increased marine fish landings and could bridge the gap between potential and current harvest.

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Keynote
Sess: 6/FM

Application of remote sensed data in marine fisheries management

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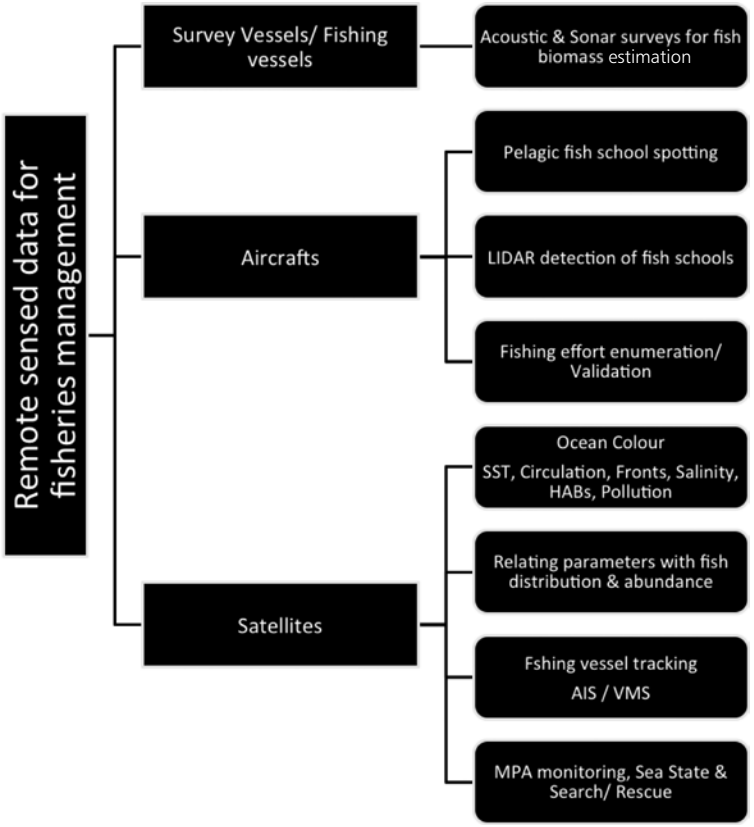
Remote sensing is the science of obtaining information about objects or areas from a distance, typically from aircraft or satellites and has multiple applications in ocean monitoring and marine fisheries management. Remote sensing data refers to data that has collected by a sensor that is not in direct contact with the area being studied or mapped. Remote sensors collect data by detecting the energy that is reflected from surfaces. These sensors can be on satellites or mounted on aircrafts or vessels. A brief description of the applications of remote sensed data is provided through the following infographic.



One of the first applications of remote sensed data in fisheries management is the use of acoustics to detect fish schools/abundance from transponders mounted on the hull of vessels. The science of fisheries acoustics is well developed and is commercially (echo sounders and sonars) used by fishing vessels to target fish. In fisheries management, acoustic surveys are undertaken by management agencies to map species wise biomasses prospectively leading to catch quotas.

The most direct and simple method of remote sensing in fisheries is visual fish spotting. Fishing fleets which exploit major fisheries such as sardines, tuna and menhaden are dependent on visual fish spotting from aircraft to direct their fleets. Its use for spotting fishing vessels (effort enumeration) has been tried in several places including the southwest coast of India, but the costs and new satellite based technology has made this redundant. A new development in aircraft/vessel based remote sensing is the use of LIDAR (Light detection and ranging) that will provide quantitative information about fish schools to depths of a few tens of meters. High powered laser systems operating in the blue- green portion of the visible spectrum (LIDAR) have shown promise for the evaluation of fishery resources. A LIDAR carried on aircraft flying at an approximate altitude of 1700 m can detect fish at depths to 16 m.

In recent years there has been an explosion in new work and technologies on use of satellites for ocean parameter monitoring. Much of the research dealing with environmental effects related to fisheries are concerned with the correlation of a single parameter with the spatial and temporal distribution of fish. However, it is most likely that fish respond to the sum total of environmental factors. Thus, it becomes necessary to correlate a large number of parameters, obtained by satellite remote sensing techniques, with fish distribution. A number of such successful correlations have been made throughout the world and also in India. Satellite remote sensing (SRS) of the marine environment has become instrumental in ecology for environmental monitoring and impact assessment, and it is a promising tool for conservation issues. In the context of an ecosystem approach to fisheries management (EAFM), global, daily, systematic, high-resolution images obtained from satellites provide a good data source for incorporating habitat considerations into marine fish population dynamics. SRS data, in conjunction with automated in situ data-acquisition systems, can provide the scientific community with a major source of information for ecosystem modelling, a key tool for implementing an EAFM.

In India, the INCOIS, Hyderabad regularly issues advisories (PFZ Advisory) to fishers on the probable location of pelagic fish schools based on thermal and chlorophyll fronts detected through satellites. India has also made a beginning in satellite based tracking of fishing vessels in the state of Maharashtra for ensuring that fishing vessels adhere to zonal restrictions. This AIS/ VMS if applied on a wider scale can also ensure monitoring and surveillance of all fishing vessels and will help to curb IUU fishing besides serving as an aid to spot vessels for launching search and rescue operations.

Thus, it is quite clear that remote sensed data will play a bigger role in marine fisheries management given the uncertainties and cost of in situ data.

Lead Article
Sess: 6/FM

Application of satellite remote sensing in estimation of potential yield from Indian EEZ

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Marine fisheries in India is an important sector with significant contribution towards the nation's GDP. Nearly 4 million marine fishermen population depend on this sector for their livelihood. Over years, the marine fish production in the country has grown from meagre 0.58 million tonnes in 1950 to the all-time high of 3.94 million tonnes in 2012 with average annual production of 3.71 million tonnes during 2011-2015. The growth in harvest of the marine fishery resources can be attributed to rapid changes taken place in the exploitation of marine fisheries in the Indian EEZ. This include manifold increase in number of fishing craft, energy intensive fishing methods, motorization of fishing crafts, extension of area of operation, introduction of multiday voyage fishing, enhanced storage facilities inboard fishing vessels, innovations in fishing gear etc. As a result there were over exploitation of several fish stocks and also the effect of climate change on fish populations. The issues popping up in the marine fisheries necessitates periodic revalidation of the harvestable potential from the Indian EEZ for formulating strategies for management and control of harvest in order to maintain harvest of different fish stocks at sustainable level.

George et al. (1977) made a pioneering attempt to estimate the fishery potential from Indian EEZ and arrived at 4.46 million tonnes for the depth zone up to 200 meters and oceanic waters. Subsequent estimates by several workers using different data sets through different methods varied between 2.03 to 5.5 million tonnes. The most recent estimate of potential yield from the Indian EEZ made by the working group constituted by the Department of Animal Husbandry Dairying and Fisheries of Ministry of Agriculture and Farmers Welfare in 2011 which is 4.414 million tonnes comprising 3.8 million tonnes from the depth zone up to 100 meters, 0.26 million tonnes from 100-200 meter depth and 0.11 million tonnes from 200-500 meter depth.

Developments in satellite remote sensing enable observation of environmental characters that affect fish populations resulting in generation of data on sea surface temperature, ocean colour, wind patterns, and ocean current. Such data can be used to derive information about chlorophyll concentration, ocean circulation features, primary productivity etc. which are some of the major factors that influence fish population abundance. Information on climatic and oceanographic factors generated through satellite remote sensing can be categorized into color based, thermal and other reflectance based derivatives which have to undergo lot of processing through a set of mathematical algorithms in order to remove noises. The final refined information

is capable of weaving a comprehensive picture of oceano-climatic dynamics of spatial domains for possible modeling of fishery resources. The chain of this modeling sequence starts with Lower Trophic Level organisms like planktons, which have a very short but sturdy and significant relationship with the primary productivity of the waters under focus. The Lower Trophic Level models thus reflect the direct impact of biogeochemical dynamics on the primary producers, which then graduates to approach the higher order animals. This paves the way for an approach which could use the primary productivity or plankton availability as the starting point and would go on to model the intrinsic and extraneous dynamics of the fishes that are prevalent in the system under focus and finally leading to estimation of harvestable potential yields of different marine fishery resources from respective regions.

Keynote
Spl. Session

Ocean Information Services and livelihood and Safety at Sea

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About 7 million people living along the Indian coastline, spanning over 8100 km, are depending on fishing for their livelihood. Locating and catching fish is always a challenging task. Often, the search for fish ends up in spending considerable time and resources, thus increasing the cost leading to low profitability. A reliable and timely advisory on the potential zones of fish aggregation will benefit the fishing community to reduce the time and effort spent in searching the shoals of fish, thus improving the profitability and hence, the socio-economic status. The concerted efforts of scientists from Earth Sciences, space and fishery science in collaboration with the coastal states have resulted in a unique service in providing 'Potential Fishing Zone (PFZ) advisories' to fishermen. Utilizing the remotely sensed data available from various satellites, this service provides advisories to the fishermen on a daily basis with specific references to 1200 fish landing centers along the Indian coast in their respective local languages.

While directing the fishermen to potential fishing zones, it is also essential to tell the fishermen about the expected behavior of sea at that location and en-route and also tell them whether it is safe to venture out into the sea on that day or next few days. The R & D efforts in that direction using the mathematical and hydrodynamic models of ocean processes lead to the operational forecast of ocean state called 'Ocean State Forecasts (OSF) services'. This service is set up to provide the information on winds, waves, ocean currents, water temperature, etc at every 3/6 hours on a daily basis for next five days. Together, these two services are helping the Indian fishermen in maximizing their economics and safety by properly planning the fishing activities.

After the devastating great Indian Ocean Tsunami on December 26, 2014, Govt. of India established Indian Tsunami Warning Centre (TWC) at India National Centre for Ocean Information Services (INCOIS). The TWC operates on 24x7 basis and provides early warnings to the coastal population warning them about the tsunami and the probable vulnerable areas in the coast. INCOIS provides all these services on operational basis in near real time for the benefit of the coastal population through various traditional and ICT enabled dissemination modes in order to provide the 'timely' information.

Indian National Centre for Ocean Information Services (INCOIS) provides these ocean information services for the benefit of various user communities in the country. The services are more fruitfully utilized when the advisories reaches the end user in timely

manner and in user readable format. Now-a-days ICT facilities in the country are accessible to large population of the country and that plays a major role in effective dissemination of information to the end user. ESSO-INCOIS has adopted the state-of-the-art technologies and tools available in the country for the timely dissemination of Ocean Information and Advisory Services that includes Potential Fishing Zone (PFZ) advisories, Ocean State Forecast (OSF), High Wave Alerts and Tsunami bulletins.

These multi-lingual PFZ and OSF advisories are disseminated during the non-ban and non-monsoon period to the entire fishermen community situated all over the entire coast of India and Islands under 14 sectors, viz. Gujarat, Maharashtra, Goa, Karnataka, Kerala, South Tamil Nadu, North Tamil Nadu, South Andhra Pradesh, North Andhra Pradesh, Orissa, West Bengal, Andaman Islands, Nicobar Islands and Lakshadweep Islands.

PFZ Advisories were disseminated in 90's using the traditional ways by using Telephone and/ or Fax. In the beginning of the 20's, PFZ Advisories were also disseminated using the Internet/ website, email and Web-GIS as mode of communication. The Web-GIS is one such advanced tool used by ESSO-INCOIS during 2002 itself thereby enabling the user to query and retrieve the advisories interest to his region. Later, with the state of art of technology available, INCOIS has designed and installed Electronic Display Boards (EDB) at major fishing harbours which have made significant impact in the delivery chain. These EDB's have undergone to various changes and lead towards the new Generation of EDB's which facilitates dissemination of satellite pictures, animations, short-films, ocean state information, disaster information and Disaster warning and alert system in addition to the normal text information.

Presently, the mobile services are also playing a major role as the mobile is now being available with most of the fishermen community in the country. Hence, mobile has been used as an effective tool for dissemination of the PFZ advisories directly to the user. ESSO-INCOIS in collaboration with various partners (NGOs, Industry, Government and Private firms) have initiated various mobile based dissemination mechanisms such as Interactive Voice Response System (IVRS), mobile applications viz. Fisher Friend Mobile Application (FFMA), mKRISHI, Voice Messages / Audio Advisories / MMS and SMS in local languages, etc. In addition to this, the advisories are also being disseminated through Local Cable TV Networks, Doordarshan, All India Radio, Community Radio's, FM Radio Stations, Local News Papers, etc.

In order to also educate the fishermen community and to assist the users in understanding the advisories thereby enabling them to use the advisories effectively, ESSO-INCOIS has partnered with Village Knowledge Centres, Village Resource Centres and other NGOs for value addition to the advisories and further downstream dissemination of the advisories to reach mass user community.

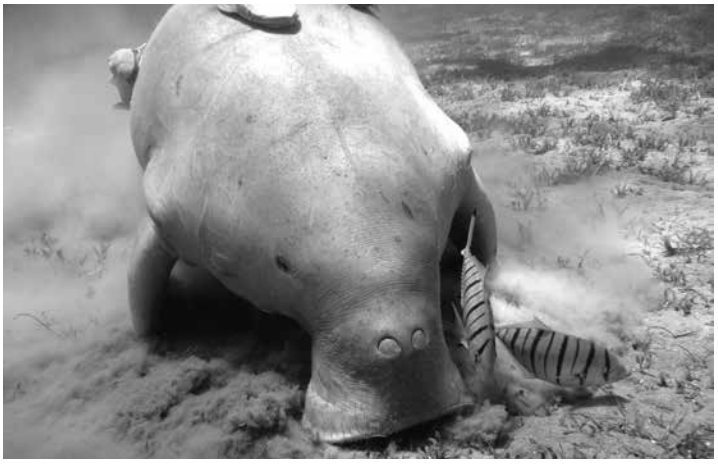
In partnership with the Industry and NGOs, an Help-line system has also been put in place in few states of India for providing the expert services to the fishermen community on the Ocean Information and Advisory Services being generated and disseminated by INCOIS. The Help-line system is available on 24 x 7 basis to provide the necessary

support to the users in terms of clarification on the ocean information and advisory services such as Potential Fishing Zone (PFZ) Advisories, Ocean State Forecasts, Tsunami Early Warnings, High-wave Alerts, cylcone information, GPS utilization, fish processing techniques, market related information, government schemes, etc.

An expert consortium is also linked to this Help-line system in order to address any specific queries raised by the users. On an average about 100 queries are answered through this Helpline system. With the usefulness of the help-line system the fishermen are demanding to make the help-line numbers as toll-free and to extend to entire coastal states of the country.

Presently INCOIS is working on an Integrated Dissemination System, named as 'Sagarvani', which is a software platform where various dissemination modes will be integrated on a single central server. The IDS includes Multi Lingual SMS, Voice Call / Audio Advisory, Mobile Apps (User / Admin modules), Social Media (Facebook, Twitter, etc.), Email, GTS, Fax, Digital Display Boards, Radio / Television broadcast units, IVRS, Cloud Channels, etc. The system also has facility to provide access to various stakeholders (NGOs, State Fishery Departments, Disaster Management Authorities, etc.) so that they too will be able to further disseminate these ocean information and alerts to the user community.

Also, in order to disseminate the information to the sailors in the deep sea, INCOIS in partnership with ISRO and Airports Authority of India (AAI) is working on satellite based disseminations through NAVIC and GAGAN systems.



Session-1
Biodiversity

BD/O-1

Spatio-temporal variation of mangrove forest in Bhatye Estuary of Ratnagiri district, Maharashtra

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Mangrove forests are among the threatened tropical ecosystems in the world. It performs multiple ecological and economical functions. A significant percentage of the coastal communities traditionally depend on mangrove for their domestic needs. Though they provide large amount of resources they have been under threat due to anthropogenic activity such as urbanization, agriculture, industrialization. The global warming effect had lead to an increase in atmospheric temperature and sea level. The change in atmospheric temperature may alter precipitation pattern and thus cause salinity stress, which will affect the growth and survival of mangrove. Rise in sea level will shift the mangrove habitat toward landside, region with limited land margin will have no scope for further expansion. Thus, it is necessary to follow proper management measure for the conservation of mangrove environment. An attempt is made in the present study to map the mangrove forest and estimate the spatial-temporal changes in the mangrove forest in Bhatye estuary. The mangrove maps of the estuary were prepared using the unsupervised classification of principal components technique of Landsat-TM, Landsat-ETM, ASTER, IRS-P6 (LISS III) satellite data 1989, 1999, 2004 and 2009 respectively. The post-classification approach was adopted for spatio temporal change detection study. In Bhatye estuary mangrove species observed were *Avicennia* spp., *Sonnertia alba*, *Rhizophora mucronata*, *Ceriops tagal* and *Acanthus ilicifolius*. The mangrove coverage of Bhatye estuary in 2009 was 152.39 ha. Mangrove extent in 1989, 1999 and 2004 were 80.42, 105.12 and 100.33 ha respectively. The spatio temporal analysis of mangrove coverage in Bhatye estuary showed an increment of 45.45 ha and degradation of 20.75 ha with net increment 24.71 ha mangrove forest during 1989-99. Next period from 1999-2004 was characterized by an increment of 25.54 ha and degradation of 30.13 ha with net degradation of 4.59 ha of mangrove forest. During 2004-2009 Bhatye Estuary showed an increment of 62.75 ha in mangrove coverage on the accreted mudflat and interior area of the estuary, while degradation of 10.89 ha in mangrove forest at certain point resulting in the net addition of 51.86 ha in the mangrove forest. The overall change in mangrove during 1989-2009 was with notable net increase of 71.98 ha and observed mostly on accreted mudflats while degradation toward the landward side at certain locality. Increment of 93.62 ha in mangrove coverage with an average rate of 4.68 ha/year and degradation of 21.65 ha in mangrove with an average rate of 1.68 ha/year was estimated in Bhatye Estuary.

Keywords: Change detection, Estuary, Mangrove, Mapping, Remote sensing

BD/O-2

Ecological observations on some symbiont bearing foraminifera from the shelf sediments of eastern Arabian Sea

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Foraminifera evolved since the Cambrian periods are abundant in the recent marine sediments, probably due to the adaptive strategies that have helped them to survive in different environmental conditions. The present study recorded small and large benthic foraminifera with endosymbionts distributed in the shelf sediments of the western continental shelf and continental slope (5-1333m) of eastern Arabian Sea, with reference to climate change and coral reef monitoring. The larger benthic foraminifera includes *Alveolinella quoyii, Amphistegina lessonii, Amphistegina gibbosa, Operculina granulosa, Heterostegina depressa* and *Amphisorus hemprichii* which have symbiotic associations with diatoms, dinoflagellates, green algae, red algae and chrysophytes. The symbionts make these forams very efficient in utilising a wide range of the light spectrum and water depths. The study showed that the species *Alveolinella quoyii* and *Amphistegina lessonii* are distributed from water depths of 30m to 1,333m showed intraspecific variations in size, always those collected from deeper waters were larger than those found in shallow waters. It is evident that the presence of endosymbionts might probably attribute to the intraspecific variations in size. The presence of relict tests of *Alveolinella quoii* along with other species of *Amphistegina* and *Operculina* are considered as the indicator species related to growth and existence of coral reefs. Therefore the occurrence of these species at various stations probably indicate the existence of coral reefs. Ocean warming and eutrophication associated with recent climate change have attributed to the decline of larger benthic foraminifera. The species belonging to these genera have evolved strategies like phenotypic plasticity and local adaptation of the concerned photosymbionts which help them tolerate thermal variations. The finding that the number of tests of LBFs decreased from shelf to slope areas may be an indication of the relation between oxidative stress, and reduced light levels that affect the growth rate of these species. It is confirmed that LBFs have a longer lifespan than the smaller forms. Foraminifera is ideal indicator organisms of the condition of reef environments since reef-building Zooxanthellate corals and foraminiferans with algal symbionts have similar water quality requirements. This implies that study of foraminiferal assemblages could be used to assess the status of coral reef environments provided by remote sensing.

Keywords: Foraminifera, Symbiota, LBF, Remote sensing

BD/O-3

Washing our colors away: A prediction of coral bleaching under different climatic scenarios

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A hyperbolic increase in the Sea Surface Temperature caused by the anthropogenic climate changes in the recent years has increased the mass bleaching of corals all over the world. However, the increasing trend and corresponding rate of bleaching vary with locations. In the current study, we tried to understand the current rate of bleaching events at Lakshadweep atolls from the frequency of the SST elevations above thermal thresholds for bleaching. The future bleaching rates for different climatic scenarios are predicted emphasizing the importance of checking the SST below threshold levels.

Keywords: SST, Coral bleaching, Lakshadweep atolls

BD/O-4

Optical discrimination of phytoplankton community structure in coastal waters, of southeastern Arabian Sea

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Ocean colour remote sensing provides a useful tool to discriminate changes in the composition of phytoplankton communities in coastal waters over spatial and temporal scales. The utility of hyperspectral optical measurements to differentiate phytoplankton composition was studied in the coastal waters off Kochi, southeastern Arabian Sea using spectral fourth-derivative analysis and clustering techniques. Cluster analysis of both absorption data and remote sensing reflectance data identified 10 clusters corresponding to 10 different groups of phytoplankton. In addition, an attempt was made to estimate the main Phytoplankton Functional Types (PFTs) and Size Classes (PSCs) from the *in-situ* data using Empirical Orthogonal Functions. The results showed that, hyperspectral Rrs(λ) can be used as a potentially

suitable input for the differentiation of phytoplankton taxonomic groups in the study region.

Keywords: Phytoplankton, Reflectance, Arabian Sea

BD/O-5

What triggers *Noctiluca scintillans* bloom in the northern Arabian Sea?

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The occurrence of *Noctiluca scintillans* bloom in the northern Arabian Sea is well documented but the mechanism that helps them proliferate still remains poorly understood. The multi-disciplinary Joint Global Ocean Flux Study (JGOFS) in the Arabian Sea attributed high productivity and export flux during the winter monsoon to large diatom bloom; they failed to observe any *N. scintillans* bloom during the winter monsoon. The occurrences of intense bloom over this basin can be traced back to 1980 as evident from NASA's Coastal Zone Color Scanner (CZCS) data and, hence, is not a new phenomenon. Recently, Gomes *et al*., 2014 suggested that unprecedented occurrence of *Noctiluca* bloom is fuelled by influx of oxygen deficient waters into surface layer. Such a spreading of hypoxic waters to the surface layer can have massive impact on the pelagic ecosystem. In this context, we studied biogeochemical conditions associated with the *Noctiluca* bloom in 2015 and also re-examined the long term oxygen data from Argo-Oxygen floats. Oxygen profiles from Argo data suggest oxic upper water column (~ 50 m) with strong seasonal shoaling. Our results do not indicate any mixed layer or photic zone oxygen depletion or any evidence of surface water hypoxia in the recent past. However, examination of Si/N climatology revealed silicate in the surface waters, which is essential for diatom growth which gets depleted at faster rate making the western Arabian Sea climatologically silicate stressed (Si/N is < 1); silicate appears to get depleted much earlier compared with the eastern counterpart resulting in a strong spatial trend. This presumably facilitates easy community transition of diatom bloom to a *Noctiluca scintillans* bloom. This might be tightly coupled with the strength of the convective mixing and winter bloom through following mechanism: silicocline being much deeper than nitracline in this part of the world ocean, a strong winter mixing will lead to a deeper mixed layer resulting in enrichment of silicate and thus facilitate diatom bloom. On the other hand a weaker winter mixing will restrict the supply of silicate to the surface layer and this will facilitate a *Noctiluca* bloom.

Keywords: Arabian Sea, Diatom, Dissolved Oxygen, *Noctiluca*, Winter monsoon

BD/P-1

Geospatial Technology: An effective tool for marine mammal conservation

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The stranding locations of marine mammals namely Blue whale (*Balaenoptera musculus*), Bryde's whale (*Balaenoptera edeni*), Fin whale (*Balaenoptera physalus*), Humpback whale (*Megaptera novaeangliae*), Minke whale (*Balaenoptera acutorostrata*) and Sperm whale (*Physeter macrocephalus*) along the Indian coast were mapped using passive method with the help of Google Earth imageries. Data was collected from published records for the period from 1874 to 2016. Once the mapping was done, hot spot analysis was carried out to identify the hot spot areas of stranding. It was seen that the west coast is more prone to marine mammal stranding. Along the east coast Mandapam-Rameswaram region in Tamil Nadu is a hot spot for stranding. It has been observed that forty two percentage of the stranding were reported from east coast whereas, fifty eight percentage of the stranding occurred in the west coast.

The static maps generated were converted to interactive web map so that it could be hosted in the web for enhanced accessibility. The interactive map was enriched with species information, reference information and standard operating procedure in case of stranding. Upon clicking each stranding location, the map will open a pop-up window with the following information *viz.* common name, scientific name, species information, name of the stranding location, coordinates, state/UT, year of stranding, reference and standard operating procedure. The web map contain the information required for field level conservationists and policy makers.

Keywords: Geospatial technology, Marine mammal stranding, Hot spot, Interactive map

BD/P-2

Mapping and conservation value assessment of mangrove diversity and distribution in Kerala coast

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Mangrove ecosystems are well known for their ecological and economic functions. Mangrove populations of Kerala coast are now on the verge of deterioration and degradation due to several natural and anthropogenic interventions. Despite extensive studies on mangrove ecosystems, the comprehensive status of regional distribution and species composition of mangroves in Kerala coast is still lacking. With this focus, the present study was designed for delineation, mapping and conservation value assessment of mangroves along the Kerala coast. Mangrove communities from 10 coastal districts of Kerala were surveyed from September 2014 to April 2015. Overall 65 contiguous mangrove patches were identified for a case study using open source Satellite Remote Sensing dataset. Ground data validation indicated 58 delineated patches of mangrove regions, out of which 6 patches are under private ownerships as aquaculture farms and land encroachments and other six are non-mangrove regions. Geo-referenced maps of all the identified patches were done using Arc-GIS tool. Data collection on species composition, mangrove type and number of mangroves/unit area of each patch was done using line intersect transect method. A total of 16 species among six families and nine genera were recorded from the entire coast, of which 14 species were recorded from the north zone (Kasargod, Kannur, Kozhikode and Malappuram) and middle zone (Trissur, Ernakulum and Alleppey) and 11 species from south zone (Kottayam, Kollam and Trivandrum). Family Rhizophoraceae was represented by four genera and seven species viz., *Kandelia*, *Bruguiera*, *Ceriops* and *Rhizophora*; Family Acanthaceae represented with single genera and three species; Lythraceae and Euphorbiaceae families represent two genera with a single species. The common species recorded were from the genera, *Avicennia*, *Rhizophora* and *Excoecaria*. Biodiversity assessment indices, the Shannon diversity (H), Simpson Index (H`) and Evenness (E) values ranged to be high (1.996, 0.828 and 0.832) in the south zone and low (1.762, 0.738 and 0.66) in the middle zone. Patch-wise ranking of mangrove diversity was calculated using Individual Value Index (IVI): Kollam ranked with high IVI value of 23.89 and the low IVI range (2.6) was noted in Trissur. The Sorensen similarity indices were low (SC = 0.5) which indicates the distant affinities between the mangrove communities of each zones. The current study suggests that regular monitoring and assessment of mangrove ecosystem is essential to understand the status, extent and homogenous distribution patterns of these critical habitats.

Keywords: Mangroves, Mapping, Biodiversity Assessment, Critical habitat

BD/P-3

Improved indices for discrimination of mangrove forests using multispectral imagery

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Mangroves of Sundarbans and Bhitarkanika act as the nursery ground for various fish species of the Bay of Bengal. Monitoring the health and dynamics of the mangroves are therefore necessary for sustainable management of the ecosystem for sustainable fishery. However, while monitoring, discrimination of mangroves from non mangroves are essential, especially where mangrove species are mixed with other vegetation types. In optical remote sensing, it is often difficult to discriminate mangrove and non-mangrove vegetation, as the radiance value is almost similar for the two classes.

In the present study an attempt has been made to develop semi-automatic extraction method multispectral imagery. An improved index, which extracts the information of the NDVI and NDWI products to produce its own range of classes for a fine distinction of mangrove species from other vegetation types, has been applied for classification. A correlation of the NDVI and NDWI outputs for Bhitarkanika mangrove forest was performed. The results showed that they are negatively correlated (-0.988), which depicted an inversely proportional relationship between the two indices when applied on this zone. Further, a simple algorithm was developed, which subtracts the NDWI values from the NVDI values at the pixel level. As the output is negatively related, subtraction increases the upper and lower range of the overall output, also increasing the distinct values of two classes with near-similar spectral signatures. Later the algorithm was applied on the forests of Jharkhali island of Sundarbans as well to test its robustness in a different type of mangrove ecosystem exhibiting a greater heterogeneity of vegetation types. The correlation was found to be -0.987, which exhibited an inverse relationship between the two indices. Further, the results were validated by Hyperspectral image (Hyperion), using Spectral Angle Mapper (SAM) technique. It is envisaged that the improved index will perform better for quick appraisal of real extent and health of mangroves and their potential for nutrient supply to the ecosystem.

Keywords: Mangrove extraction, Landsat 8 OLI, NDVI, NDWI, Hyperion, SAM

BD/P-4

Studies on the benthic polychaetes of Kadalundy estuary, southwest coast of India

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This study documents the result of field studies conducted in the two distinct regions of Kadalundi-Vallikunnu community reserve-a mangrove and estuarine ecosystem on the southwest coast of India, during pre-monsoon, southwest monsoon and post monsoon seasons to assess the macrobenthic faunal composition and abundance in relation to the environmental variables. The benthic fauna of Kadalundy estuary was assessed from two distinct areas, mangrove and estuary. Two transects were taken from each areas during three seasons. The hydrographical conditions of the region marked seasonal variation in salinity. The pre-monsoon period was dry with less rainfall and maximum salinity (32.1) was observed during this period. The southwest monsoon is characterised by heavy rainfall and low salinity both in surface and bottom waters. The seasonal variation reflected in the temperature pattern also. The variation in the dissolved oxygen was not considerable. The results of phytoplankton abundance also showed seasonal and spatial variation, the concentration of chlorophyll-a (Chl-a) was relatively high in the station near the mangrove area. Macrobenthic faunal analysis revealed the presence of polychaetes, molluscs and crustaceans. Studies on the seasonal variation of macrobenthic components revealed that the largest benthic population occurred during the pre and post monsoon period and minimum during the south west monsoon period. This decrease is attributed to the sharp decline in salinity. The phytoplankton biomass (chlorophyll-a) also showed similar seasonal pattern and it appears that there is direct correlation between benthic production and organic production in the Kadalundi estuary. Mangrove ecosystem was rich in crustaceans whereas estuarine ecosystem was rich in polychaetes. The present study revealed the existence of a marked seasonal variation in the abundance of polychaete community in the study area. Relatively higher number of polychaetes was observed during the pre-monsoon season. Members of family Eunicidae were the most abundant in the polychaete community. Presence of Capitellidae members from the mangrove regions indicate eutrophication due to the anthropogenic inputs and land run off. Kadalundy estuary is one of the major stopover point for many migratory and shorebirds. The abundance of common sandpiper and lesser sand plover which prey upon the polychaetes was recorded from estuarine station during pre-monsoon period indicating a trophic relationship of avian fauna with macrobenthic community. As polychaetes are the indicators of a healthy aquatic environment, their periodic monitoring and assessment will serve as effective tool in environmental impact analysis and management of any vulnerable ecosystem.

Keywords: Benthic community, Polychaetes, Kadalundy estuary, Trophic structure

BD/P-5

Habitat mapping of intertidal molluscs of Dakshina Kannada coast, Karnataka using remote sensing and GIS techniques

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Geographical Information System (GIS) and remote sensing have been widely used in coastal management as they provide the information on coastal landforms and habitat structure of benthic organisms. Synoptic view and repetitive coverage provided by satellite images can be effectively used to generate database and the required information on coastal environment and resources can be analyzed in a better way by using these techniques. In the present study, an attempt has been made to delineate various changes in the selected Intertidal habitats (Someshwar, Panambur and Sasihithlu) along the coastline of Dakshina Kannada district of Karnataka state and to characterize these habitats which provide shelter to intertidal organisms including molluscs. In addition, the proposed study aimed at understanding the threat faced by molluscs due to various factors. The study was carried out from November 2016 to September 2017.The mapping of the coastline of Dakshina Kannada has been carried out using topographical maps and Indian remote sensing satellite imageries (IRS-Resourcesat 2-LISS-IV). The topographical maps were georeferenced using ground control points (GCPs) so as to integrate them with other spatial data. The satellite data has been processed by using the ERDAS IMAGINE 9.1software and analyzed by ArcGIS 10.1. The resulted coastal maps were used to estimate the geomorphologic changes and shifting of the shoreline position due to erosion and accretion. The positions of sampling sites were recorded using GPS. The abundance and species richness of molluscs noted in the field were linked to the spatial data. Shoreline changes were correlated with diversity changes within intertidal mollusc communities. The study revealed the abundance of molluscs in the intertidal zone of Someshwar and species richness in Panambur. The mutilated/time series data has helped to generate a database for the coastline of Dakshina Kannada by integrating RS and GIS techniques. The variation in land use land cover during the study period has been analyzed. The changes occurred in the coastline during the study, due to industries and anthropogenic factors have been discussed, which help in the implementation of conservation measures and to protect the sensitive habitats of the shelled organisms.

Keywords: GIS, Remote sensing, Habitat, Intertidal molluscs

BD/P-6

A multi-method approach for marine phyto planktonic community structure determination with special emphasis on High Performance Liquid Chromatography (HPLC) and Scanning Electron Microscopy (SEM)

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Remotely sensed satellite data of ocean colour give overall picture of phytoplanktonic composition for larger stretch of ocean water, whereas *in-situ* spatiotemporally geo-tagged water collection with subsequent analysis by various laboratory tools such as the High-Performance Liquid Chromatography (HPLC), Light Microscopy (LM) and Scanning Electron Microscopy (SEM) help in determining the planktonic composition of the marine environment at highly spatial and temporal resolution. The lab methods not only validate the remotely sensed ocean colour data for phytoplanktonic community structure, but also complement each other.

In this connection, we standardized an HPLC method for simultaneous quantitative analysis of a wide range of planktonic carotenoid and chlorophyll pigments from the marine waters of Indian coast. The HPLC system employed was that of Shimadzu with a binary pump system, a 100 μl capacity Rheodyne injector, a C18 guard column, a 250mm long Phenomenex C18 column with 5 um particle size, a SPD-M20A photodiode detector and a gradient elution system using combination of methanol and ammonium acetate buffer. The chromatograms were analysed using the LC Solution software provided by Shimadzu Corporation. The method had high response factor (RF) and regression coefficient (R2) as well as down to sub-nanogram levels of the limit of detection (LOD) and limit of quantitation (LOQ) for 14 phytoplankton pigments analysed, confirming high linearity and sensitivity of the method. The appearance of identical and pigment specific absorption spectra at specific retention times both for the calibration standards and the water samples confirm to the specificity of the method. Water samples from Palk Bay and Gulf of Mannar collected during normal days and during days of *Trichodesmium* blooms in the Gulf of Mannar were analysed. While the quantitative HPLC data on the spectrum of phytoplankton pigments can be used for determining the phytoplankton community structure through chemical taxonomy algorithms such as the CHEMTAX, parallel water samples were also subjected to light microscopy (LM) to determine the

community structures as a complementary technique. While, as an adjunct to HPLC and LM, SEM is crucial in establishing the taxonomic position of the planktons, which highly laborious, time consuming and technically demanding. Nevertheless, we tried to bring about certain level of simplicity and flexibility to the SEM of planktons from marine water by successfully drying the plankton samples with hexamethyldisilazane (HMDS), which helped in the long-term storage of the dried samples before SEM examination at a facility situated far away from our lab.

Keywords: Community structure, HPLC, SEM, Phytoplankton

BD/P-7

Detection of *Noctiluca scintillans* bloom in the northern Arabian Sea using chlorophyll fluorescence from MODIS-AQUA

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Northern Arabian Sea frequently encounters *Noctiluca scintillans* bloom every year and one such bloom was observed during 10th-22nd February 2017. Generally, the phytoplankton blooms are identified based on the biomass or the chlorophyll concentration from satellite data. However, this paper presents the utilization of chlorophyll fluorescence as an indicator or tool for detection and identification of phytoplankton blooms. For this study, a bloom event that occurred in the northern Arabian Sea as mentioned above was identified and assessed using the *in-situ* bio-optical and hydrographic filed observations acquired during the bloom. MODIS Fluorescence Line Height (FLH) product was used along with chlorophyll concentration were correlated and found a very good correlation with an R^2 value of 0.74. In contrast, the band ratio chlorophyll product of MODIS showed inconsistency with *in-situ* chlorophyll data due to interference of other constituents. The high FLH value patches >0.18 were conformed to be located at the medium to high concentration of *Noctiluca* bloom. The result showed that MODS FLH, enhanced RGB imagery and *in-situ* data are reliable tools for phytoplankton bloom detection.

Keywords : MODIS, FLH, Chlorophyll, *Noctiluca scintillans*

BD/P-8

Tessellation of Indian geographic region based on proximity to the Wildlife Protected Areas

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The 11th Article of Aichi Targets of Convention for Biological Diversity (CBD) calls for conserving at least 27 percent of overall geographic area (17 percent of terrestrial and inland water areas and 10 percent of coastal and marine areas) by 2020. However, official records indicate that India currently has only about 3 to 4 % (1.62 Lakh km2) of its area under protection. This indicates that India would have to bring much more area under the protected status within a short span of time. A first step to this process can be identification and delineation of range of the influence of current protected areas. The outcomes of any ecological processes depend heavily on the boundary that provides its inputs. As protected areas are designed to conserve the habitats of the endemic, endangered or vulnerable species, their objectives and priority species of conservation varies. Nevertheless, irrespective of the focal species of conservation such restricted areas and shelters, supports large diversity of other species populations from the anthropogenic threats. Such variations in the species occurrence and the difficulty in having a uniform quantitative variable of diversity that can be measured for these regions demands the delineation of boundary of influence based on the available qualitative features like the extent of area protected. Voronoi diagram supports the development of such qualitative and ambiguous representation of space. In the present work, Voronoi tessellation is used to partition the entire geographic area of India based on the proximity to the protected areas. Thematic maps of the protected areas were collected from database of ENVIS Centre of Wildlife Institute of India, Dehradun and were digitised to extract vector point and boundary features. Voronoi tessellation interpolation of the point data was performed using 'deldir' package R 3.3.1. A weighted Voronoi mapping is attempted using 'gclib' package with area of the region as the weights. The output of this work, the tessellated polygons indicating the proximity towards Indian Wildlife Protected Areas were converted to Keyhole Markup Language (KML) format and are deposited in the open access institutional repository of ICAR - CMFRI, eprints@CMFRI. Identification of further criteria and their employment for widening the areas under protection status can be a future area of research in this line and the current work will definitely add to this.

Keywords: Voronoi diagram, Species distribution, Diversity

Session-2

Aquatic Environment and Ecology

AEE/O-1

A generalized algorithm for retrieval of the chlorophyll concentration from satellite data in coastal and inland waters

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With the advent of many new generation sensors designed to provide frequent, high-spatial resolution, visible and near-infrared images, satellite optical remote sensing has been increasingly recognized as an effective method for producing synoptic maps of phytoplankton biomass distribution in the coastal zones and associated inland water systems. However, estimation of the chlorophyll concentration as an important proxy for representing phytoplankton biomass from remote sensing data is often erroneous when based on the reflectance ratios in two or more bands in the blue-green range or a combination of the reflectance peak position and magnitude in the red-near-infrared range. The present work aims to propose a generalized algorithm for retrieval of the chlorophyll concentration from both multispectral and hyperspectral data, provide a rigorous validation of the retrieved chlorophyll concentration using independent *in-situ* data, and demonstrate its performance based on a variety of remote sensing data from the contrasting inland, coastal and ocean environments. Results from the new algorithm showed good agreement with measured data with errors within the desirable limits. The new algorithm is more advantageous when compared with other algorithms in terms of retrieval accuracy, wider applicability, and compatibility with modern satellite optical remote sensing sensors.

Keywords: Chlorophyll, Remote sensing, Coastal ecosystem, Inland ecosystem

AEE/O-2

Observation of satellite derived sea surface temperature (SST) and pCO_2 distribution over the Bay of Bengal and Arabian Sea and its relation to chlorophyll variability

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The sea surface temperature (SST) products have been processed to generate SST images over the Bay of Bengal and Arabian Sea using INSAT-3D and MODIS-Aqua sensor datasets during two different seasonal months covering December 2013 & 2014 and April 2014 & 2015. The daily and 8-days/weekly, monthly scale composite SST images have been generated using GHRSST, MODIS-Aqua and INSAT-3D images. With respect to the daily synchronous satellite pass time of MODIS-Aqua, the INSAT-3D 13:30 hrs pass data have been archived over the study area to process SST images for comparison. The SST values has been observed in the range of 24-32°C. To understand the air-sea interaction in terms of the partial pressure of CO_2 measurements over the Bay of Bengal and Arabian Sea, the satellite derived SST data have been utilized to generate pCO_2 images using SST based algorithm. This algorithm has been used over the Indian water to observe the pCO_2 variability and its ranges in two different seasons. The overall pCO_2 ranges were observed to be around 350-700 μatm. The INSAT-3D derived 30-minutes interval images has been processed on intra-day basis with the 48 passes on a day. The pCO_2 images showed the direct proportional relationship with the SST images. The day time images showed increased pCO_2 and the night time images showed the decrease in pCO_2 for the Bay of Bengal and Arabian Sea cloud-free regions. With the increase in SST by 1-2°C, there has been observation of increase in pCO_2 by 2-5%. The comparison of pCO_2 on weekly and monthly time scales using the GHRSST, MODIS-Aqua and INSAT-3D data were found to be interesting. This study is a preliminary attempt to understand the hourly, daily, weekly, monthly and seasonal trend of SST and pCO_2 variability over the Bay of Bengal and Arabian Sea using two different satellite datasets. Monthly composite chlorophyll images were compared with monthly pCO_2 images of Arabian Sea and Bay of Bengal to relate the variability in chlorophyll with pCO_2. The study will be helpful to understand the air-sea interaction, ocean acidification and biogeochemical processes. The *in-situ* pCO_2 measurements and validation would be very much useful for the regional scale algorithm development.

Keywords: MODIS-Aqua, pCO_2, INSAT-3D

AEE/O-3

Revisiting the deep chlorophyll maxima in Bay of Bengal in context to phytoplankton adaptation in low light biophysical environment

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The variability in deep chlorophyll maxima (DCM) in conjunction with temperature, salinity and photic depth characteristics from central Bay of Bengal was investigated during 2015 and 2016 coinciding with spring Intermonsoon. In 2015, a prominent low salinity cap (31-33 psu) was observed beyond 85°E and 17°N impinging till a depth of 60 m. In contrast, surface water was marked by uniform salinity (< 32.0 psu) till 88°E and decreased thereafter suggesting intrusion of low saline surface water from northeast. Chlorophyll fluorescence within the top ~ 50 m was negligible during both the investigations (85°E-95°E) indicating extreme oligotrophic condition. The location of DCM shoaled between 50 to 100 m in 2015, on the contrary, a stable DCM was observed in 2016 at a depth of ~ 75 m co-varying with light levels upto ~ 9 μmol $m^{-2}s^{-1}$ (< 1%). This suggests existence of strong phytoplankton population adapted to very low/negligible light regimes. In this paper we discuss our present understanding of these communities discovered recently from similar known biophysical environment in the northern Arabian Sea.

Keywords: Phytoplankton, Deep chlorophyll maxima

AEE/O-4

Using remote sensing imagery to assess impacts of *El Niño* variability on oceanic primary producers

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Phytoplankton are at the base of the food chain and transfer energy to higher trophic

levels. This transfer of energy has a knock-on effect on fisheries and dependent human societies especially in highly productive and coastal upwelling regions. Phytoplankton respond rapidly to climate-driven perturbations, including the dominant mode of variability in the Earth-climate system generated by the *El Niño* phenomenon. Recently, marked variations have been observed in the centroid of anomalous warming in the Equatorial Pacific under *El Niño*, associated with quite different teleconnection patterns. Using remote-sensing observations and reanalysis datasets, we differentiate the regional forcing mechanisms, and compile an atlas of associated impacts on oceanic primary producers caused by two extreme types of *El Niño*. We show robust evidence that during Eastern Pacific (EP) and Central Pacific (CP) types of *El Niño*, impacts on primary producers can be felt everywhere, but tend to be greatest in the tropics and mid-latitudes, encompassing up to 67% of the total affected areas, with the remaining 33% areas being located in high-latitudes. Our analysis also highlights considerable and sometimes opposing regional effects. During EP *El Niño*, we estimate decreases of −56 TgC/y in the tropical eastern Pacific Ocean, and −82 TgC/y in the western Indian Ocean, and increase of +13 TgC/y in eastern Indian Ocean, whereas during CP *El Niño*, we estimate decrease of −68 TgC/y in the tropical western Pacific Ocean and −10 TgC/y in the central Atlantic Ocean. The atlas of impact of EP and CP types of *El Niño* on oceanic phytoplankton can be used for societal benefit. It provides key climate impact information that can allow us to better inform fisheries management on possible risks and opportunities associated with *El Niño* events, and support more effectively mitigation and adaptation plans for local fisheries-dependent societies.

Keywords: *El Niño*, Phytoplankton, Eastern Pacific Ocean, Central Pacific Ocean

AEE/O-5

Application of remote sensing in identifying the salinity fronts and their influence on the biological production of the Bay of Bengal

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Fronts, the dynamic interface between water masses of distinct hydrographic characteristics, are ubiquitous features of oceanic regions. As a zone of intense lateral and vertical mixing with a concomitant effect on the nutrient replenishment of the surface waters, fronts are sites of enhanced primary production, which in turn gets channelled to higher trophic levels in the pelagic food web. Hence studies on frontal zone are getting worldwide interest. Compared to the Pacific Ocean and the Atlantic Ocean, the knowledge on frontal structure and its influence on the productivity pattern of the Indian Ocean is limited. Bay of Bengal, the eastern part of the northern Indian Ocean receives an enormous amount of fresh water in its north. This in turn contributes

to the development of salinity fronts in this Bay. Remote sensing is considered as the most cost effective tool to accomplish oceanographic monitoring and research at a large and trans-boundary scales. Hence, using satellite data, first we have affirmed the presence of the salinity fronts. Then, the *in-situ* data collected were used to cross check the frontal structure. These narrow three-dimensional regions were characterized by a nutrient rich environment than their contiguous waters. This in turn had a profound influence on the phytoplankton and zooplankton community of the Bay of Bengal.

Keywords: Fronts, Productivity, Bay of Bengal, Salinity

AEE/O-6

Shrinking of lakes: A comparative study between a protected and an unprotected lake in Mumbai, Maharashtra

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Understanding the status of the water body with respect to shrinking, water quality, biodiversity etc helps in adopting effective management measures. We made an attempt to assess and compare the status of Powai and Vihar Lakes of Maharashtra in terms of shrinking of lake area, water quality and plankton diversity. Powai Lake is situated in the suburban area of Mumbai whereas Vihar Lake is located in Sanjay Gandhi National Park, and thus protected from anthropogenic influences. Differences in the water spread area for Vihar and Powai Lake at temporal as well as spatial scale were calculated. Satellite imageries from Landsat MSS for 1973 and Landsat 8 for 2015 were used in the GIS environment to calculate the differences in area. Raster data imagery was converted to vector data in forms of polygons for study area and the difference was calculated using Arc GIS 10.1. Results from satellite data indicates that, substantial reduction was observed in Powai Lake area of about 27% decrease in 2015, when compared to 1973, whereas there is no significant shrinking observed for Vihar Lake rather an increase in the area of lake was observed. Physicochemical and biological evaluation proved that, Powai Lake is organically polluted and low in biological diversity, whereas Vihar Lake is comparatively more diverse and less polluted but reached the threshold level of water quality parameters and requires concerted efforts to maintain the quality and biodiversity. Shrinking of Powai Lake might also have contributed for the increased pollution state of the lake as shown by the prevailing physico-chemical parameters. Area reduction, plankton diversity and water quality of the lakes has been mapped in GIS platform. Findings from this study can serve as baseline information for detailed studies in near future and also help in devising remedial measures to prevent the deterioration of health of the lake ecosystem. Enhancing public awareness, scavenging polluted sediments,

bioremediation, proper regulatory measures for anthropogenic waste disposal and strict measures to prevent further encroachment to the catchment area are needed for the restoration of Powai Lake.

Keywords: Landsat, GIS platform, Physico-chemical, Powai Lake, Vihar Lake

AEE/O-7

Observed and modelled chlorophyll trends along Indian coastal waters: A synergistic approach using numerical model and satellite data sets

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Marine phytoplankton play a critical role in regulating the marine ecosystem and global climate and vice versa. Distribution of chlorophyll along the coastal region is highly important for the fishery. Hence the impact of changing climate on coastal primary productivity has to be taken seriously. Underlying physical processes also play a significant role in regulating the chlorophyll availability to surface through mixing and also through lateral advection.

In this study, synergistic use of coupled biogeochemistry-physical model and satellite data sets have been used to understand the change in coastal productivity over climate scenario and the impact of surface and subsurface physical process on the productivity with a special emphasis on Indian coastal waters is addressed. The coupled model was configured for global ocean with a spatial resolution of 25 km and an inter-annual simulation was performed from 1981–2016 using ERA fluxes as the forcing data sets. Study based on coastal chlorophyll analysis requires the use of pixels as close to shore in order to represent coastal processes. In this study, three ocean points near to coast were used. The distribution and trend of different model and satellite parameters such as chlorophyll, SST, nutrients, wind etc were analysed in the study. From the monthly climatology (1981-2016) of surface chlorophyll from model for the coastal points for the latitudes from 10^0N to 16^0N in Bay of Bengal (BoB), it was observed that BoB is highly productive during southwest monsoon and winter period. Monthly anomalies of surface chlorophyll for the high productive months (June, July, August, November and December) were calculated by subtracting the mean chlorophyll of that month over the study period from the chlorophyll levels of certain month. A decreasing trend in chlorophyll activity was observed in almost all months. Further analysis is to be carried out to understand the trend of chlorophyll in other coastal regions of India and the role of physical processes.

Keywords: ERA, Climatology, Phytoplankton

AEE/O-8

Impact of large scale climatic events on chlorophyll and SST pattern in Arabian Sea and Bay of Bengal through remote sensing

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This work presents the trend analysis and relationship between chlorophyll-*a* (Chl-*a*) concentration and sea surface temperature (SST) in the Arabian Sea (AS) and Bay of Bengal (BOB) using Aqua MODIS Level-3 Standard Mapped Image (SMI) data for a period of approximately 13 years (2003–2015). An attempt has been made to analyse the monthly, seasonal and annual trends in Chl-*a* (as an index of phytoplankton biomass) and SST in various regions of Arabian Sea and Bay of Bengal and results analysed in context of ENSO events. The various regions were categorised as north, south, north-west, north-east, south-west and south-east for both AS and BOB excluding the Gulf regions. Different regions of AS and BOB exhibited different trends in SST and Chl-*a* when compared to basin scale average trend. Inter- annual variability for all the regions were analysed using the monthly trends in Chl-*a* and SST. The major warm events showed high SST values in all regions of AS during 2003, 2005, 2010, 2014 and 2015, most of which were the *El Niño* years. Chl-*a* revealed lower values during all the warm event years in all the regions of AS. Different patterns were observed in BOB, 2004 and 2015 were the warmest of all for various regions of BOB. However, the magnitude of Chl-*a* concentrations did not show significant variations. In most of the regions of AS and BOB the effect of *El Niño* and *La Niña* was observed little late, though the duration and magnitude differed in different regions. An improved understanding of such events will help to predict the effect of such events on the marine ecosystem and fisheries of the region.

Keywords: Arabian Sea, Bay of Bengal, Chlorophyll-*a,* ENSO*, La Niña*, Sea surface temperature

AEE/O-9

Seasonal variation of Ekman mass transport and upwelling indices in Arabian Sea and the associated productivity changes using SCATSAT-1 wind fields

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In this paper SCATSAT-1 level 4 analyzed wind fields on daily basis from October 2016 to August 2017 have been used for analyzing the coastal Ekman mass transport. The Ekman mass transport was resolved into alongshore and across shore components using the instantaneous slope of the shoreline. The magnitude of the offshore component is considered to be an index for the amount of water upwelled from the base of the Ekman layer. The seasonal variations of Ekman mass transport have been studied by analyzing monthly averaged Ekman transport for coastal regions of Oman as well as for Indian coastal areas of eastern Arabian Sea. It has been observed that very strong Ekman mass transport (around 3000 km/s per m of coastline) occurs near the Oman-Yemen coast during the SW monsoon beginning June and continuing upto August. In order to confirm upwelling activity near Oman coast during the SW monsoon concurrent use of GHRSST sea surface temperature data (SST) has been analysed post and prior to such high Ekman transport. It has been observed that there is a cooling of the surface waters and an across shore SST gradient exists near the Oman coast.

In order to analyze the productivity change due to upwelling during SW monsoon, MODIS 8 day composite chlorophyll data has been used. Due to unavailability of chlorophyll data during monsoon, chlorophyll concentrations for the Oman coast was analyzed pre and post monsoon. The 8 day composite chlorophyll-*a* concentration from MODIS Aqua for the end week of August 2017 shows increased chlorophyll concentration covering entire Oman-Yemen coast. The chlorophyll-*a* concentration reaches as high as 3-4 mg/m^3 and the bloom extends offshore as far as 200km from the coast.The eastern Arabian Sea adjoining the Indian peninsula also experiences seasonal variation of Ekman transport due to the reversing wind patterns. Ekman mass transport for this region starts increasing from April and with the onset of SW monsoon gets stronger and extends northwards. By July high Ekman mass transport perpendicular to the coast can be seen for eastern Arabian Sea extending as north as 16ºN. MODIS Aqua chlorophyll data pre and post monsoon shows increased productivity during late August as compared to May. The upwelling areas are major sources of nutrients and are thus conducive for the growth of phytoplanktons as well as zooplanktons and are also the potential fishing zones.

Keywords: Chlorophyll, Ekman mass transport, SCATSAT, Upwelling

AEE/O-10

Surface water monitoring and vegetation analysis of Saraiya Man Lake using remote sensing

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Saraiya Man, eight kilometers from Bettiah in the West Champaran district of Bihar state, India is an oxbow lake that offers vivid fish diversity and used as a source of livelihood since ages by the local fishermen. Over years, the lake has suffered drastically from many dimensions especially depletion in the fish diversity due to shrinkage in the water extent and reduction in the water level both as well as declination in the riparian cover due to establishment of new villages around the lake. In order to sustain the fish diversity and the lake, it is necessary to monitor the surface water of this lake on spatial and temporal scales. Over years, the remote Sensing technologies has made great strides and contributed massively in the management of natural resources, disaster management and environment monitoring. These technologies are effectively being used to assess the surface water extent and quality that are the key factors in defining the Total Maximum Daily Loads (TMDLs). The present study discusses the approaches of remote sensing techniques applied in assessing the change in water extent and quality of the lake and also assess change in the riparian cover using the Indian Remote Sensing Satellite data (Panchromatic and Multispectral) of different time periods of the lake. *Bhuvan*, an Indian Geo-Platform of Indian Space Research Organization was used to download the satellite data of different time periods for the study area. For surface water monitoring to assess changes in water levels, water extents and turbidity, Principal Component Analysis (PCA) was done and to assess change and loss in vegetation cover, normalized difference vegetation index (NDVI) was applied. The findings from the study provide a constant but irregular pattern of reduction in vegetation cover and unsteady change in surface water extent and level both. Similarly, the unsteady change in turbidity was also noticed.

Keywords: Normalized difference vegetation index, Remote sensing, Saraiya Man, Surface water monitoring

AEE/P-1

Annual cycle of vertical structure of chlorophyll distribution in the northeastern Arabian Sea

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The northeastern Arabian Sea (NEAS) experiences two seasons of phytoplankton blooms. The first blooming season occurs during June–September, when the upwelling shallows the thermocline and advects nutrient rich water to the surface. The upwelling is weak compared to the southern part of the eastern Arabian Sea. The second blooming season, also known as the winter phytoplankton bloom occurs during November–February. This bloom is driven by turbulent entrainment mixing owing to sea surface cooling. The surface cooling is in turn forced by cold dry wind blowing over the sea surface. There occurs a short period of detrainment bloom, in early March, following the winter bloom.

Much attention has aroused on the impact of physical processes on phytoplankton distribution in the NEAS. After unraveling the fact that the advection of low-saline water by the West India Coastal Current (WICC) inhibits the entrainment mixing in the southern part of NEAS during winter months and the inhibition of mixing has its consequence on chlorophyll distribution based on monthly climatological atlases of chlorophyll, temperature, salinity and currents. This has motivated us to take a fresher look at the region using more fine resolution (in time) data available from ARGO floats. There are five floats in the NEAS which sample at a frequency of once in 10 days and each float has measurements of more than 50 profiles during 2015-2017. These floats are able to measure physical variables such as temperature and salinity, and chlorophyll. We present temporal variation of the annual cycle of vertical structure of these variables using the ARGO data. The findings are compared against fine resolution satellite derived chlorophyll data.

Keywords: Arabian Sea, ARGO, Chlorophyll, WICC

AEE/P-2

Assessment of chlorophyll-*a* vertical profiles in the tropical Indian Ocean over six decades

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Under climate change, physical conditions in the ocean are being modified. Here we explore possible consequences for a fundamental biological property, namely the vertical structure of the chlorophyll field in the tropical Indian Ocean (30° to 120°E; 30°S to 30°N). Areas of similar features of the study area were identified by applying Principal Component Analysis and Cluster Analysis to monthly climatologies of chlorophyll-*a* extracted from Ocean Colour Climate Change Initiative data. Vertical structure of chlorophyll during the three consecutive twenty year time periods viz. 1951-1971, 1972-1992 and 1993–2013 are compared in each of the areas so identified. Chlorophyll variability within these areas was then related to the prevailing physical conditions such as wind velocity and mixed-layer depth (MLD). Information on wind was obtained from the National Centers for Environmental Prediction / National Center for Atmospheric Research reanalysis data, and on MLD was calculated from temperature profiles obtained from World Ocean Database 2013. In general, total number of vertical profiles of Chl-*a* were more in the recent decade, which could be due to the advancement in sampling and monitoring techniques. Fluctuations in the vertical Chl-*a* profile was found to be more during the summer monsoon, when compared to other seasons.

Keywords: Tropical Indian Ocean, Chlorophyll-*a*, Cluster analysis, Mixed-layer depth

AEE/P-3

Validation of aerosol optical thickness over the coastal waters of southeastern Arabian Sea

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The aerosol products derived from the standard ocean colour missions were validated with sun-photometric measurements of Aerosol Optical Thickness (AOT) from off Kochi, southeastern Arabian Sea during January 2015-September 2016. The average *in-situ* AOT at 870 nm was between 0.125 and 5.21 for the study period. The median of absolute relative differences between satellite and *in-situ* aerosol optical thickness at 870 nm varied between 2% to 64% for the different missions and months. The differences tend to be higher in monsoon months. These insights can be used to study the relationship between marine aerosols and phytoplankton in the region, as aerosols are known to enhance phytoplankton growth by providing a source of nutrients and trace metals.

Keywords: Aerosol optical thickness, Southeastern Arabian Sea, Ocean color

AEE/P-4

Prevalence of mesoscale eddies and chlorophyll variability in the southeastern Arabian Sea

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Mesoscale eddies are capable of mediating chlorophyll variability through physical-biological coupling. In the present study, satellite derived Sea Level Anomaly (SLA), chlorophyll-*a* (Chl-*a*) and Sea Surface Temperature (SST) data for the period 1998 - 2016 were utilized to pinpoint the occurrence of mesoscale eddies and associated Chl-*a* variability in the southeastern Arabian Sea (SEAS). The Okubo-Weiss criterion was used for the identification and tracking of eddies from the said region. The results indicate the presence of cyclonic (cold core) and anti-cyclonic (warm core) eddies during the summer and winter monsoon seasons. The variability of Chl-*a* was well evidenced in the

presence of these eddies during the same period. We attempt to relate the evolution and propagation of mesoscale eddies to Chl-*a* variability, the overall importance of such features and their influence on biological production in the SEAS.

Keywords: Mesoscale eddies, Chlorophyll-*a* variability, Okubo-Weiss criterion, Southeastern Arabian Sea, Remote sensing

AEE/P-5

Additive influence of nutrients on primary productivity along the northeastern Arabian Sea

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Bio-geologically significant nutrients like nitrates, phosphates and silicates were analyzed to study the additive influence on the productivity of the ecosystem. Chlorophyll-*a* (Chl-*a*) is a principal productivity pigment present in the marine ecoregion, which is considered as a proxy for productivity. Sampling was carried along off Gujarat coast of Arabian Sea, from October 2013 to March 2017 (N=90). Generalized Additive Models (GAM) were known to back fitting the algorithm to combine different smoothing or fitting methods. The statistical methods currently supported are local regression and smoothing splines. GAM is used to models, specified by giving a symbolic description of the additive predictor and a description of the error distribution. In the current study, the model is used to fit the algorithm between nutrients (silicates, phosphates and nitrates) as independent parameters and chl-*a* dependent (predictor) parameter. Regression parameters for the model are intercept (-0.12731) and slopes (silicates -0.03306; phosphates 8.44213; nitrates 0.22808). Nutrients like phosphates and nitrates were found to have significant impact ($p<0.001$) on Chl-*a*, whereas silicates did not have any significant impact. Finally, the three nutrients together explained 56.80% of deviance on Chl-*a*. Results conclude that the studied nutrients, *i.e.*, nitrates and phosphates are showing significant impact on the productivity along the study region. Phosphates ($Pr>|t| = 1.65e-10$) are showing strong positive significant impact than nitrates ($Pr>|t| = 4.07e-07$), which proves that phosphates are acting as limiting nutrients along the region.

Keywords: Chlorophyll-*a*, GAM model, Phosphates, Nitrates, Northeastern Arabian Sea, Primary productivity

AEE/P-6

Evaluation of empirical and semi analytical downwelling diffuse attenuation coefficient models along the coastal waters off Cochin

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Development and validation of the downwelling diffuse attenuation coefficient (Kd) models derived from the remote-sensing reflectance are important in satellite monitoring of optical water quality, estimation of primary productivity and modeling underwater light availability in oceanic as well as coastal waters. However, the *in-situ* measurements on downwelling diffuse attenuation coefficient are lacking along the coastal waters off Cochin. Seasonally reversing wind, and change in the circulation pattern along with enormous fresh water discharge from Cochin Estuary define the biogeochemistry and optical properties of coastal waters off Cochin. The profile measurements on remote sensing reflectance (Rrs) and downwelling diffuse attenuation coefficient (K_d) in all the visible spectrum were calculated from *in-situ* profile of downwelling irradiance (Ed) and upwelling radiance (Lu) recorded using Satlantic hyperspectral radiometer. This study presents the evaluation of the empirical and a semi analytical diffuse attenuation coefficient models and compares the results with *in-situ* measurements from four bathymetry stations along off Cochin region from March 2015 to February 2016. The evaluation results showed that the QAA models derived values are close to the *in-situ* values of K_d (490), optical depth (OD) and euphotic depth (Eu), whereas, Tiwari and Shanmugam (2014) model performance is somewhat lower than the QAA model but better than the Mueller operational model. Hence, the results obtained in this study, showed that QAA model might be improved for the accurate retrieval of K_d at 490 nm. QAA derived K_d (490) showed a good correlation coefficient with *in-situ* K_d (490) ($R^2 = 0.89$), and low root mean square error (RMSE = 0.182). Thus, the present study underpins the necessity of a new model for the improved estimation of K_d at 490 nm along the coastal waters off Cochin which would provide a better understanding of optical water clarity and underwater light availability along the coastal waters off Cochin.

Key words: Primary productivity, Remote sensing reflectance, Muller operational model

AEE/P-7

Impact of tropical Indian Ocean warming on phytoplankton biomass concentration in the southeastern Arabian Sea using satellite observations

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The Arabian Sea renders itself as one of the most productive regions in the world, due to diverse physical processes during summer and winter. Rapid warming during the recent years in the tropical Indian Ocean is known to affect the Arabian Sea basin as well. Here, light is not usually a limiting factor, but the increased stratification of the water column associated with the rise in ocean warming suppresses the nutrient mixing from subsurface layers. This can lead to a decrease in the phytoplankton biomass and the primary productivity of the euphotic zone, with serious implications on fishery. Satellite data of chlorophyll-*a* (Chl-*a*) concentration, SST and related physical forcing mechanisms for a period of 19 years from 1998 to 2016 have been analysed to study the influence of variations in chlorophyll concentration and SST in the functioning of the southeastern Arabian Sea ecosystem. The influence of SST on chlorophyll is studied on a monthly, seasonal and interannual basis. This will help in the elucidation of a clear picture regarding the fluctuations in primary productivity during summer and winter. The four seasons considered for the analysis were 1) winter monsoon (Dec-Feb), 2) pre-monsoon (Mar-May), 3) summer monsoon (Jun-Sep) and 4) post-monsoon (Oct-Nov). It has been observed that summer monsoon is associated with the highest Chl-*a* concentration that support primary productivity of the south eastern Arabian Sea followed by post-monsoon season. This study examines the role of the warming of tropical Indian Ocean in the recent years and the associated changes in mixed layer processes in bringing shifts in the timing of peak chlorophyll in the south eastern Arabian Sea and the trend in annual variations in phytoplankton biomass concentration.

Keywords: Arabian Sea, Chl-*a*, Indian Ocean warming, Phytoplankton, SST

AEE/P-8

Study on the consequence of climate change on ocean-climatic features along southwest coastal waters, India

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Marine ecosystems are maintained by the energy flow from the sun to various trophic levels linked through food webs, where primary producers are considered as the base of food webs. Keeping the view of climate change related consequences on marine ecosystem, one can arrive at some fundamental postulations like whether the trends have irrevocably emerged or is there any cyclicity in the trend and also the extent of co-influence of one factor on other, thereby throwing light on possible bio-oceanological paradigms, which are of immense help in forging ahead with forecast of many components of the marine ecosystem. Towards fulfilling this goal, a concerted spatio- temporal matrix based approach on ocean-climatic features along southwest coastal water of India has been attempted through this study. Satellite remote sensing data on chlorophyll-*a*, sea surface temperature, wind flow, precipitation pattern, etc. were retrieved at different depth strata and were co-integrated for pattern matrices on both spatial and temporal facets.

Keywords: Chlorophyll-*a*, Ecosystem, Sea surface temperature, Wind flow

AEE/P-9

Winter chlorophyll variations in the northern Arabian Sea

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The northern Arabian Sea is home to a chlorophyll bloom in boreal winter, attributed to convective vertical mixing driven by cold and dry northeasterly winds during that season. The amplitude of this bloom varies interannually. The current study aims at describing and understanding northern Arabian Sea winter interannual chlorophyll variations from observations (including remotely-sensed chlorophyll data and physical parameters derived from Argo data). Different remotely sensed

chlorophyll products reveal consistent interannual surface chlorophyll variations, although the amplitude of these interannual signals varies considerably between products. However, there are large discrepancies on the linear surface chlorophyll trend between the different products.

Our results suggest that anomalously high chlorophyll signals in the AS during winter result from deeper than usual MLDs, which are themselves controlled by net heat fluxes at the air-sea interface. Our study therefore demonstrates that the mechanisms controlling chlorophyll variations at seasonal timescales also operates at the interannual one. All observed surface chlorophyll products exhibit a modest negative correlation with ENSO and a weaker correlation with Indian Ocean Dipole (IOD). *El-Niño* events drive weaker monsoon, less convective overturning and hence a weaker chlorophyll bloom. Our analysis also indicates a negligible impact of Indian Ocean Dipole on the winter chlorophyll bloom.

Keywords: Chlorophyll bloom, ENSO, *El-Niño*.

AEE/P-10

Assessment of oceanographic variables in Indian Ocean during 2030, 2050 and 2080 under RCP scenarios and its implications

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Global warming and the consequent changes in climate patterns have profound impacts on marine fisheries in India. Marine and coastal ecosystems are extremely vulnerable to variations in oceanographic variables induced by climate change. The present study assessed the possible changes in oceanographic variables in Indian Ocean during 2030, 2050 and 2080, under different Representative Concentration Pathways (RCP) scenarios (RCP 2.6, RCP 4.5, RCP 6.0 and RCP 8.5). The oceanographic variables considered for this study under four RCP scenarios were sea surface temperature (SST), chlorophyll concentration (Chl), sea surface salinity (SSS), precipitation (Pr), pH and sea level rise (SLR). Future projections of these variables along with their causes and impacts were analyzed based on a suitable model simulation of the fifth phase of the Coupled Model Intercomparison Project (CMIP5) under World Climate Research Programme (WCRP). In each of the three time slices, SST and SLR show a rise in trend whereas SSS, Chl and pH show a declining trend relative to 2015. Precipitation shows a rise in trend relative to 2015 but variations occur in each time slice. In 2080, SST shows a projected variation of (0.69ºC to 2.6ºC), SSS (0.49-0.75 psu), SLR (12.7-19.1 cm), Pr (0.26-0.6 mm/day), Chl (0.013 to 0.043 mg/m^3) and pH (0.04-0.24) relative to 2015. Analysis by region was done to identify areas of significant changes and spatial impact of these variations in

Arabian Sea (AS) and Bay of Bengal (BoB). Information on climate projections and their impacts will help policy planners to devise proper adaptation planning.

Keywords: Representative concentration pathways, Sea surface temperature, Chlorophyll Concentration, Salinity, Precipitation

AEE/P-11

Variability of *in-situ* and satellite derived reflectance of *Trichodesmium* during bloom and non-bloom regions in southeastern Arabian Sea

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The absorbance and reflectance behaviour of phytoplankton in bloom conditions are different and much complicated than the normal situations. *Trichodesmium*, in addition to its bloom-forming capacity, has gas vacuoles that makes it buoyant and keeps it near the surface (within the upper 20 m), where colonies can be more readily detected. The present study was part of the summer monsoon cruise of Sagar Sampada (No. 274) conducted in 2010, where *Trichodesmium* was found in the phytoplankton community in the form of bloom and otherwise. The study area was southeastern Arabian Sea between 9° 34' N to 15° 16' N off west coast off India. The remote sensing reflectance (Rrs) spectrum during *Trichodesmium* bloom showed anomalous behavior, which could be due to the reflectance from the above water due to the presence of thick patches of algae. The Rrs from satellite and *in-situ* measured values showed good correlation in the wavelengths 412, 443, 488, 531, 547, 667 and 678 nm during non bloom conditions whereas in the bloom condition Rrs showed a bias, *i.e.*, satellite Rrs showed lower values without affecting the shape of the curve. At the bloom region, Rrs values from satellite decreased to zero beyond 675 nm whereas radiometer measured *in-situ* data showed higher values. The more concentrated samples of *Trichodesmium* were found to show the characteristic "red edge" in their spectrum, shifting the peak to wavelengths between 710 and 730 nm. Using modeled hyperspectral remote sensing reflectances, it is proved that *Trichodesmium* was indistinguishable from other phytoplankton at concentrations less than about 1.0 mg Chl/m^3. Phytoplankton acts as a main influencing IOP component for the Remote sensing reflectance measured by satellite. The increased phytoplankton concentration in the ocean surface directly affects the light availability in the water column and in turn may affect the remote sensing observations by satellite. In-situ sampling of *Trichodesmium* bloom has to be carried out with much careful observation

as it is difficult to get the homogenised water column for the inherent optical studies. Therefore, detailed studies are needed to design different algorithms for bloom and non-bloom situations, at least in Case 2 waters.

Keywords: Phytoplankton absorption, Remote sensing reflectance, South Eastern Arabian Sea (SEAS), *Trichodesmium* bloom.

AEE/P-12

Impacts of Indian Ocean Dipole on upwelling and downwelling along the west coast of India

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The characteristic property of the west coast of India is the seasonal reversal of west India coastal current (WICC) and also the seasonal evolution of upwelling and down-welling. WICC feeds the upwelling zones along the west coast of India when it flows equatorward, during the south-west monsoon and feeds the down-welling zones during north-east monsoon and winter while moving poleward. The upwelling along the west coast of India is mainly driven by wind induced Ekman divergence, whereas down-welling along the coast is driven by the propagation of coastally trapped Kelvin waves. Annual primary productivity over the eastern Arabian Sea (EAS) is greatly dependent on the upwelling and down-welling along the west coast of India. During the Indian Ocean Dipole events, EAS exhibits significant dynamic as well as thermodynamic variability. Upwelling along the west coast of India was considerably decreased during the positive IOD years compared to negative IOD and normal years. Over the west coast of India, down-welling also decreased during the positive IOD years 1994, 1997 and 2006. During these years, westerly winds were replaced by easterlies over the equator in the northeast monsoon. This resulted in the collapse of propagation of down-welling favorable Kelvin waves from the equator. The inter-annual variability in upwelling and down-welling was evidently reflected in the Chlorophyll – *a* concentration along the west coast of India.

Keywords: Upwelling, Indian Ocean Dipole, Downwelling

AEE/P-13

Spatio-temporal variability of optical classes in coastal waters of India: Classification based on satellite remote sensing reflectance

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Visible spectral radiometry provides information on phytoplankton cells and other optical constituents present in the surface waters of the ocean. Studies on the delineation of Indian coastal waters based on ocean-colour radiometry are very limited. In the current study, we present results on identification and characterization of optical classes in the Indian coast using the satellite-derived Remote Sensing Reflectance (Rrs) datasets at six different wavebands (412, 443, 490, 512, 555 and 670 nm), corresponding to the SeaWiFS (Sea-Viewing Wide Field-of-View) sensor for the years 1998-2013. Normalization and log-transformation of Rrs values was done, based on the method of Mélin & Vantrepotte,2015. Eight optical classes have been defined using a Fuzzy C mean classification approach on the log10-normalized reflectance spectra. Spatial and temporal variations of the optical classes reflected dynamic physical and hydro-biological processes at different time scales. Seasonal variations of optical classes in seven sediment basins (DGH, 2006-2007; Biswas, 2012) of Indian waters are described and explored on their ecological significance. The seven sedimentary basins are Saurashtra basin, Mumbai basin and Kerala-Konkan-Lakshadweep basin on the west coast; Krishna-Godavari basin, Mahanadi basin, Bengal basin and Andaman-Nicobar basin on the east coast. We used mean reflectance spectral signals to characterize the optical classes as Case-1 and Case-2 waters, as defined by Morel and Prieur, 1977 and Prieur and Sathyendranath, 1981. Optical classes 1-6 are categorized as Case-1 waters and classes 7-8 as turbid Case-2 waters. Optical diversity index (H) ranged from 0 to 1.3. During the intermonsoon and northeast monsoon seasons, the values of optical diversity tend to be high in deep waters (>100 m) off southwest, southeast and Andaman & Nicobar regions. In the southwest monsoon, optical diversity ranged from 0.5 to 1 with relatively few pixels representing high index range of >1. Regions with low optical diversity index of 0 to 0.2 are mostly confined to turbid basins with high riverine influx. The chlorophyll concentration of optical classes 1 to 5 ranged from 0 to 1 mg m^{-3} and for optical classes 6 to 8, it ranged between 1 to >3 mg m^{-3}. Spatio-temporal variations of optical classes are also related to changes in chlorophyll concentration and suspended sediment influx.

Keywords: Marine ecosystems, Sediment-basins, Ocean colour, Optical classes, Biological significance

AEE/P-14

Interannual variability of oil sardine fishery over the eastern Arabian Sea

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Based on the earlier studies on small pelagic fishery over the Eastern Arabian Sea, it is evident that environmental forcing and climatic events have a significant influence on the variability of fish population and hence the catch. The Arabian Sea is one of the most biologically productive oceanic provinces in the Indian Ocean. Since the seventy percentage of annual fish landing belongs to the eastern Arabian Sea, it has pronounced economic importance as compared with the western Arabian Sea. The small pelagic fishes are highly vulnerable to environmental variability due to their biological characteristics (plankton feeders, short lifespan and high mobility). The present paper attempts to study the impact of oceanographic process and climatic events on Indian Oil Sardine fishery along the eastern Arabian Sea. Catch statistics of Indian Oil Sardine landings along the west coast of India are highly fluctuating since 1985. The highest catch was recorded in 2012 and the least were in 1994. These three decades (1985-2015) significantly displays varying oceanographic conditions and major climatic events. This study reveals that the Indian oil sardine fishery is highly fluctuating with respect to the variability in sea surface temperature (SST), chlorophyll-*a* concentration and extreme climatic events.

Keywords: SST, Chlorophyll-*a*, Oil sardine

AEE/P-15

Stocks of oceanic phytoplankton carbon from remote sensing: New estimates and opportunities

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Oceanic phytoplankton carbon stocks are fundamental to carbon fixation in the ocean and global carbon cycle. An accurate estimation of these stocks, however, is a non-trivial task. Recent developments in estimating phytoplankton carbon from remote

sensing will be presented. Estimates of phytoplankton carbon based on a novel ocean-colour-based algorithm that combines cellular allometric properties and light-absorption properties of phytoplankton will be presented. Further, new results based on a data assimilation experiment to estimate phytoplankton carbon will be shown. The similarities and differences among various estimates of phytoplankton carbon from ocean-colour methods and data assimilation will be presented. Further challenges in obtaining the carbon stocks in various phytoplankton types, and minimizing the estimation uncertainties, will be discussed.

Keywords: Phytoplankton, Carbon cycle, Allometric properties

AEE/P-16

Ocean warming: Evidence on SST increase after 25 years from inshore waters adjoining Cochin, southeastern Arabian Sea

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Climate change has greatly impacted sea surface temperature (SST), pH, annual rainfall, cyclones etc which is being established through satellite derived remotely sensed datasets. Validity of these data is enhanced through ground truth data. We present here the marked differences in SST, Chl-*a*, NPP and in the levels of certain dissolved nutrients from the inshore regions of Cochin by comparing the *in-situ* data generated during 1988 (on board *RV Cadalmin*) and 2014 (*FRV Silver Pompano*).

The annual mean of SST during the year 2014 was 0.35 °C higher than during 1988, while the subsurface water near bottom registered an increase of 0.1°C only. It was interesting to note that except temperature the levels of dissolved nutrients, chlorophyll *a* and NPP were significantly low during 2014. We could confirm that the increase in SST along the Cochin coast since 1988 is in the range of 0. 35 – 0.4 °C.

Keywords: Occean warming, SST, Chl-*a*, Ground truth data, Southeastern Arabian Sea

AEE/P-17

NF-POGO Alumni Network for Oceans (NANO)– activities in a nutshell

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In 1999, as an aid to the implementation of an international and integrated global ocean observing system, the directors and leaders of major oceanographic institutions around the world created a forum called the Partnership for Observation of the Global Oceans (POGO). Today, POGO is a partnership of institutions involved in oceanographic observations, scientific research, operational services, education and training, with 37 member institutes from 19 different countries that works closely with other international and regional programmes and organisations. POGO conducts regular training programmes thereby enabling young scientists all over the world to become experts in advanced techniques of ocean research. POGO activities are generously supported by Nippon Foundation (NF).

Together, NF and POGO believe that understanding the ocean and coastal environments relies on the existence of an integrated observing system around the world maintained by qualified decision-makers, researchers and service providers. Prof. Trevor Platt, FRS, the then Executive Director of POGO; Dr. Shubha Sathyendranath, the then assistant Executive Director of POGO and Dr. Sophie Seeyave, the then scientific co-ordinator of POGO founded NANO (or NF-POGO Alumni Network for Oceans) to redress the acute deficiency in trained oceanographers to work for the benefit of society through dedicated research on oceans. Thus, NANO is today a global network of past and present NF-POGO scholars held together by a common interest in, and commitment to, ocean science, and by the common will to communicate the results of their work to the general public, so that they can be applied for the benefit of society at large. The alumni are drawn from capacity building activities which include shipboard training programmes (transects along the North South Atlantic Transect (NoSoAT), a cruise to the Porcupine Abyssal Plain (PAP) Sustained Observatory, the Atlantic Meridional Transect (AMT) cruise and the FRidge cruise); Visiting professor programmes (2004–2007) wherein reputed scientists provide training in their own area of speciality by spending three to six months with local scientists and students; Centre of Excellence (CofE) programme (since 2008) wherein ten scholars per year from all over the world are trained at the NF-POGO Centre of Excellence at Alfred Wegener Institute, Germany for a period of ten months in integrated, multi-disciplinary oceanography; and the CofE Regional Training programme of 2-3 week duration focused on specific topics. Realising the importance of international

collaborations for oceanographic research, NANO brings together top scientists from all over the world, especially from countries that have hitherto been underrepresented in international programmes and organisations. International collaborations have resulted in implementing joint projects assigned to different regions–Carribean, Indian sub-continent, Latin America, North west Africa, South East Asia. These projects stand testimony to the fact that through joint planning and exchange of information, the community can make better use of the limited resources available. Every year, selected NANO alumni meet with representatives of the Nippon Foundation and POGO Secretariat to review the progress of the NANO activities and to make detailed plans for the upcoming year. NANO and POGO do not set scientific goals, but focus attention on implementation issues such as technical compatibility among observing networks; shared use of infrastructure; and on public outreach and capacity building.

Keywords: POGO, NANO, PAP, Capacity building

Session-3

Socio-Economics and ICT

SE/O-1

Resonance between scientific findings and indigenous knowledge of fishing communities along the South African east coast about climate and environmental change

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Fishing communities are very susceptible to environmental problems arising from global climate change, such as sea level rise, flooding and changes in marine ecosystems. Consequently, their livelihood becomes threatened as they depend on marine living resources as a source of income, food security and nutrition. Due to the uncertainty related to climate change and the likely need for adaptation, it is important to engage the local communities to understand their perception of climate change and whether it resonates with the scientific findings. In this study, a reduced Rapid Vulnerability Assessment (rRVA) was used as tool to extract local indigenous knowledge about climate change through a series of workshops with the fishermen and women. This method is adopted from a previous study conducted on the west coast of South Africa to guide the data collection and analysis. Initial results from the rRVAs performed on the west coast reveal that even though observation and perception of fishers with respect to climate change and environmental variability can be represented on a defined timescale, it is not always possible and well-defined. Furthermore, despite the spatial differences between observations of locals and the analysis of regional patterns in scientific literature, there is correlation in some trends. This study uses other sources of evidence of environmental and climate change such as rainfall, temperature, wind, and chlorophyll data as well as aerial images of the region from the late 80s to this date. The understanding of resonance between these two sources of knowledge is useful in ensuring effective environmental education and ownership of environmental problems, adaptation and mitigation measures by the local people. This shows that participatory management of fisheries and coastal areas is fundamental in building up socio-ecological resilience to environmental and coastal issues.

Keywords: Environmental change, Fishing livelihood, Indigenous knowledge, Participatory management

SE/O-2

Physical and biological interactions during a cyclonic event in the Arabian Sea

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Tropical cyclones represent an extreme case of air-sea interaction. It is well known that Sea Surface Temperature (SST) is one of the key parameter that control the genesis and intensification of cyclones. The tropical cyclones are driven by air-sea heat fluxes from the ocean and are generally developed over warm ocean surfaces with temperature greater than 26°C. Tropical cyclone produces significant changes in the underlying ocean vertical thermohaline structure. Cyclone induced sea surface cooling and the enhanced biological productivity has been widely reported in the past. The cyclone induced near inertial oscillation and the resultant turbulent mixing can enhance the vertical nutrient flux from the thermocline region and cause phytoplankton blooms in the near surface water. The present study is focusing on the ocean mixing dynamics and its role on the surface chlorophyll-*a* variability during the passage of cyclone "Nanauk' over the Arabian Sea. *In-situ* data sets from a moored buoy located at the Arabian Sea and remote sensing data sets such as SST, sea surface height anomaly, wind speed and chlorophyll are used for the analysis.

Keywords: SST, Wind, Chlorophyll, Arabian Sea

SE/O-3

Fish identification app - a quick guide for the students

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New opportunities can emerge from combining mobile and advanced networking technologies. An app called Fish Id which is an Android Native, and works offline has been developed. It's just a plug and play app, and could be used offline once it is installed. Fish app supports up-to Android 7 (Nougat). Programmes and policies supporting further development of ICT in fishing communities and education sectors must effectively link the relevant stakeholders from local to international levels. The advancements should be designed to cater truly for the needs of the poor and lead towards more

responsible fisheries. Mobile technology has made the information dissemination faster and cheaper. Information and communication technology is a fundamental development tool to support information sharing, collaboration and dialogue leading to increased participation and ownership. Co-management is a central plank in sustainable fisheries and usually includes a need for data collection and sharing. For any such step in fisheries the resource must be correctly identified. Field identification is the major bottleneck in marine fisheries and this could be overcome by using ICT. The problems faced in the use of communication technology like less coverage of radio transmission and its frequencies especially while at sea or in landlocked areas can be overcome by the use of this user friendly app.

Keywords: Mobile app, Android, Offline

SE/O-4

Disaster preparedness - valuable lessons from the field in the aftermath of Ockhi cyclone

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The cyclone Ockhi which manifested itself as one of the most pertinent forms of nature's fury had wrecked widespread havoc in the form of loss of innumerable human lives, materials, environmental losses and above all left more than 250 people missing from Kerala alone. A field survey was undertaken to the fishing villages of Vizhinjam and Poonthura of Thiruvananthapuram district which was worst affected in the State. Focus group discussions and freewheeling interviews was used to collect data from the fishers. Data was collected on the number of people who died at sea, who went missing at sea as well material losses incurred. The perceptions of the fishers as to the lack of disaster preparedness during the calamity was assessed and a major plan of action incorporating the key factors/elements for disasters preparedness in future was arrived at.

Keywords: Disaster preparedness, Ockhi, Early weather warning systems, Safety devices.

SE/P-1

Development of micro level environment management guidelines for coastal villages

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The coastal ecosystems are impacted by anthropogenic activities and the habitats of many estuarine resident and migratory fauna are getting degraded. The studies conducted by ICAR-Central Marine Fisheries Research Institute (CMFRI), during the past two decades have shown that the water quality in the industrial area of Vembanad Lake is affected. Moreover, recent studies have also pointed out the threats faced due to plastic and other litter in the coastal habitats. Understanding the need to develop micro level environment management plan, the CMFRI initiated studies in Cochin backwaters during April 2017. The objectives of the study were to evaluate the different types of pollution affecting the productivity of the coastal water and to develop an implementable EMP for the villages. The management part is expected to be a participatory approach, with co-management of the resources once the habitat degradation is reversed. A coastal village (Mulavukad), was selected for the study. A GIS map delineating the micro level boundary was prepared for baseline survey of Mulavukad Panchayath, Ernakulam District, Kerala, India. Sampling stations (51) were fixed, making use of the google earth imageries. The criteria for locating the sampling points were *viz*. open backwaters, shrimp farms (operational and non operational), inland water bodies, canals running through populated areas and mangroves. Subsequently, the ecosystems under assessment were sampled for water, sediment and biota, to arrive at the health status of the same, based on the physical, chemical and biological analysis. Water samples were analysed for various parameters such as salinity, nutrients, ammonia, dissolved oxygen, BOD, COD etc. Sediment characteristics (Eh, pH, organic carbon etc.) were also noted, through laboratory analysis. Microbial load in each station was also evaluated. Along with this, the quantity of waste generated in each household, the waste management methods and other issues like clogging of canals by litter and water hyacinths were noted. The local governing bodies were also involved in these activities. The results of the studies indicating the health of the coastal habitat is presented in the paper. Suitable GIS maps will also be generated which would help the planners and administrators to effectively plan their program depending on the intensity of the ecological problem. The suggestions and action plans for reversing the environmental degradation will be discussed.

Keywords: BOD, COD, Dissolved oxygen, Ecosystem

SE/P-2

Use of remote sensing to address government policy requirements with respect to eutrophication of coastal and marine waters

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To meet our obligations towards responsible management of marine resources, the ecosystem status and its variability have to be monitored in a systematic and sustained manner. In this context, remote sensing, with its ability to monitor any location on the earth on a daily basis and at high spatial resolution (of order 1 km), and over long periods of time in a cost-effective manner, offers an indispensable observation tool. It is particularly important to monitor aquaculture sites for evidence of eutrophication, to ensure healthy and sustainable ecosystems. For example, the European Marine Strategy Framework Directive requires that incidences of eutrophication in European waters be reported. According to the Directive, eutrophication is determined on the basis of whether or not a particular threshold value in chlorophyll is reached at any time, at any location. *In situ* monitoring methods, by themselves, can only provide this information at a few select locations. In combination with remote sensing, it becomes possible to provide maps of eutrophication at every single location of interest, with the *in-situ* measurements providing anchor points for local and regional validation of satellite products. The use of a single threshold value of chlorophyll for identifying eutrophication at all locations may not be ideal. A more versatile approach to monitoring eutrophication might be to first establish a baseline of phytoplankton dynamics for each location of interest, and then monitor those locations for signs of change from the established norm. If such an approach is adopted, then time series of satellite data can be used to establish the statistical properties of phytoplankton dynamics (peak values, timing of peaks, frequency distribution around peaks) over a defined number of years, against which the behaviour of phytoplankton in the current year can be evaluated. In this presentation, we demonstrate how such a method was implemented for UK waters.

Keywords: Eutrophication, Remote sensing, Chlorophyll

SE/P-3

Assessment of impact of past and future shoreline changes using remote sensing & GIS: A case study of Kanchipuram district in Tamilnadu

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Climate change is likely to cause many modifications along the coast leading to more flooding, inundation, loss of infrastructure and lives. Assessment of past and future shoreline changes in the coastal areas will help to assess trend in the changes, particularly in the densely populated regions. Satellite data of Landsat MSS of 1980 with 60 m resolution, Landsat ETM+ of 2003, Landsat OLI of 2015 with 30 m resolution, SRTM digital elevation model (DEM) data of 30 m and topographical maps of Survey of India (SOI) were used to study the changes in the coast of Kanchipuram District. Spatial analysis and image processing were carried out using ArcGIS version 10.5, ERDAS Imagine 2014, and ground truth verification was carried out using Juno 3B GNSS. The changes in the shoreline were mapped for the periods 1980 - 2015 and the impact of erosion or accretion on the coastal resources was assessed. Evaluation of potential loss of productive land under sea level rise was carried out by incorporating the land use/ land cover (LULC) using spatial analysis in ArcGIS platform.

Land use pattern of 2015 indicated the extent of different important land resources such as Pallikaranai swamp land, salt pan, agriculture lands and lakes. Digital shoreline analysis system used for the assessment of long term changes revealed that 98.78% of the coastal length was under erosion and 1.22% was under accretion from 1980-2015. The extent of loss was 874 ha along 87 km coast length between 1980 and 2015. LULC overlaid coastal elevation showed that inundation areas were covered by agriculture land, salt affected land, wetland and water bodies. IPCC has predicted that the change in SLR will be 0.34 -1.45 cm/year. Our analysis indicated that inundation of area would be 6181ha by 2049. The coastal population (nearly 7.67 lakhs) that depends on the coastal resources for their livelihood are likely to be affected. The severity of changing shoreline and predicted SLR impact will lead to loss of infrastructure facilities, productive lands and salinization of rivers. Systematic site specific approach integrated with intensive monitoring at regional scale is very much needed to prevent further loss of lands.

Keywords: Impact assessment, Remote sensing, GIS, Sea level rise, Shoreline changes

SE/P-4

A trans - disciplinary approach in comparing vulnerabilities across the selected ocean hotspots and implications for adaptation to global climate change - lessons from the GULLS project

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The GULLS project, 'Global learning for local solutions: Reducing vulnerability of marine-dependent coastal communities' funded by the Belmont Forum since 2014, has been investigating five regional 'hotspots' of climate and social changes, such as southeast Australia, Brazil, India, South Africa, the Mozambique Channel and Madagascar. The research programme has been divided into five inter-linked components: ocean models, biological and ecological sensitivity analyses, system models, social vulnerability, policy mapping, communication and education. Following the standard vulnerability elements of exposure, sensitivity and adaptive capacity, the vulnerabilities of coastal communities and other stakeholder's dependent on marine resources in the five hotspots is compared using a set of indicators derived and populated from results of the research programme. The implications of similarities and differences between the hotspots for adaptation planning and options will be assessed and is expected to build regional skill-sets that can reduce coastal vulnerability by evaluating and characterizing likely impacts and create predictive systems. This will inform decision makers about the expected consequences of coastal changes, deliver alternative options in terms of adaptation and transformation within coastal communities and helps in defining the long term implications of selecting a particular option in terms of economic, social and environmental outcomes.

The Indian hotspots region identified for the study includes southern Kerala and Tamil Nadu, where the five inter-linked components: ocean models, biological and ecological sensitivity analyses, system models, social vulnerability, policy mapping, and communication and education have been attempted across environment, resources and resource users. This paper provides impacts consequent to climate change under the components specific to Indian climate hotspot region. The project proposes the need for involving the primary stakeholders in the proactive planning, adaptation and mitigation mechanism under the framework of Climate Resilient Village Adaptation and Mitigation Plan (CReVAMP). The project envisages experienced fishers, committed women, proactive youth and articulate children as climate change agents for the future. The GULLS underscores the fact that climate impacts are global but adaptation and mitigation solutions are local.

Keywords: Climate change, Vulnerabilities, Ocean hotspots, Adaptation & mitigation

Session-4

Aquaculture

AQ/O-1

Development and assessment of remote sensing and GIS based decision support system for planning and management of the coastal aquaculture

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Aquaculture has been a fast growing food producing sector with the annual growth rate of 6% worldwide. In India, shrimp aquaculture has grown tremendously since 1990, by utilizing around 1,75,000 ha of coastal land that contributes 6.62% of global aquaculture production (73.8 million tonnes) at present. The unregulated fast growth has raised environmental issues such as conversion of lakes, mangroves and agricultural lands to aquaculture farms, salinization of soil and drinking water resources adjacent to aquaculture farms. Earlier survey estimates indicated that 0.65 million ha in the east coast and 0.55 million ha in the west coast are suitable for the development of brackishwater aquaculture in India. The present level of utilization of 14 % indicate the huge scope for expansion, but this assessment will vary in the present context due to Coastal Aquaculture Authority (CAA) Act that calls for environmental restrictions and compulsory buffer zone between land classes for the development of aquaculture. Multiple spatial criteria such as land resources availability, water quality, soil characteristics, water availability and environmental regulations need to be considered for planning the aquaculture. Remote sensing and GIS have been used for the decision making as it permits additional spatial data incorporation and advanced analysis to identify the suitable sites from the unused coastal resources without multi-user conflicts.

Three dimensional approach *viz.* land use, soil and water characteristics have been used in the present study to identify suitable areas for sustainable aquaculture. LISS III data has been used for mapping land use pattern and incorporated site specific soil and water resources characteristics in GIS along with ground truth verification to identify the location and extent of the suitable areas available for expanding brackishwater aquaculture in Nagapattinam district of Tamil Nadu, India as a case study. Combining these multiple criteria, the weighted overlay analysis in Arc GIS 10 indicated that suitable area of 2261 ha is available in addition to the existing 4172 ha of shrimp farms. To our knowledge, this is the first study which provides information on the extent, location, prior land-use of potential area for aquaculture with soil and water characteristics. The study can serve as a model to assess the resources availability for expanding brackishwater aquaculture based on three dimensional approach in the country.

Keywords: Aquaculture, Decision support system, Development, GIS, Remote sensing

AQ/O-2

Deriving useful products for managing water quality impacts on aquaculture using multiple methods and earth observation data

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Aquaculture is a growing industry worldwide, with the potential to meet many of the sustainable development goals such as food security and poverty alleviation. However, a number of environmental challenges affect the aquaculture industry and present a threat to its expansion. A number of these challenges revolve around poor water quality as a result of microbiological contamination, or Harmful Algal Blooms. Monitoring water quality, and managing its impacts on aquaculture, requires consistent, and spatially and temporally well-resolved, measurements of the dynamic coastal ocean environments where operations are normally conducted. This itself is a challenge, but one that is progressively being met with the aid of Satellite Earth Observation imagery.

Presented here are several case studies using data from the newest generation of Earth Observation Satellites to provide insight into microbiological hazards and Harmful Algal Blooms that affect aquaculture around the United Kingdom. High resolution optical data were obtained from the Landsat 8 OLI and Sentinel 2 MSI sensors, whilst medium resolution optical data were obtained from the MODIS, MERIS, VIIRS and Sentinel 3 OLCI sensors. Data have been used as part of Harmful Algal Bloom classification, river plume detection, cell size estimation, and biotoxin predictive modeling. Iterative processes of stakeholder engagement were used to develop a bulletin service and derive new use cases for the data (including marine insurance).

Keywords: Aquaculture, Ocean colour, Sentinel 3, Harmful algal blooms, Biotoxin

AQ/O-3

Integrating water quality levels and remote sensing facilities to estimate aquaculture distribution in Egypt

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This paper is a review on the integration of water quality and remote sensing applications for some of the main components of aquaculture, including location, facility, market, pollution, and its ecosystem impact. Fish farming issues, also, can address the impact of the aquaculture industry, human population growth, trend extrapolation and future sustainability of aquaculture. The extent of the effects of pollution varies depending on where the aquaculture facilities are located, which species are kept, how densely they are stocked and feed used.

Water quality is considered as one of the most important factors affecting fish yield in aquaculture. Certain water quality parameters such as suspended matter concentrations, turbidity, salinity, coloured dissolved organic matter, chlorophyll and temperature can be effectively monitored by remote sensing techniques. Remote sensing images may help to inform researchers and planners about water quality trends that are occurring over a broad area in which fisheries and aquaculture activities occur. However, the operational use of remote sensing in Egyptian aquaculture remains limited. Therefore, there is a need to increase the incorporation of both observational of modeled data on spatial and temporal scales to detect water quality in fish ponds and to enhance the utility of remote sensing in aquaculture.

This paper reviews relation between the water quality and the Egyptian inland fisheries and aquaculture distribution and growth using remote sensing tools. The review will concentrate on the availability and relevance of usage of this tool in aquaculture, depending on available recent data particularly from the Egyptian Ministry of Irrigation, the Egyptian Ministry of Agriculture and FAO data base.

Keywords: Aquaculture, Remote sensing, Water quality.

AQ/O-4

Application of remote sensing and GIS in the selection of suitable marine aquaculture sites along Gujarat coast

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The indigenous technological innovations in open sea mariculture have proved its viability and feasibility in Indian scenario during the past decade. At present it is one of the leading policy focus for the Union government as well as for all maritime states. Now the sea farming activity is under promotion with a mission mode approach. The rapid expansion of mariculture is heading towards the berthing of a new marine aquaculture industry in the country. Farming activities in the inshore, open sea and offshore waters creates conflicts while competing for marine space between the different users. The farmers, entrepreneurs and promoters evaluate the potential open sea offshore sites based principally on accessibility, biological, technical feasibility, and especially cost concerns. Due to ocean dynamics, establishment of sea cage farms in open waters involve complex and difficult procedures. Hence, it is essential to select proper site which is ideally suitable in terms of ease of operation, risk and economic feasibilities. The remote sensing and Geographical Information System (GIS) is a powerful tool to develop models for earmarking suitable potential locations for sea farming and to make sustainable management of mariculture sites. The present study was a pilot one to identify some of the suitable, ideal locations for sea farming along Gujarat coast. To map the locations, the available physico-chemical and oceanographic parameter data obtained from Landsat 8 and MODIS satellite data were pooled and used on GIS based platform. By using those criteria, the maps were layered, and were combined to generate a final output showing the "most suitable, suitable, moderately suitable and unsuitable" locations for open sea mariculture development. The results of the study suggest that the open sea cage mariculture could potentially be developed in the open waters along the Gujarat coast and the relevance in making Marine Spatial Planning (MSP) using ArcMap. A complete suitable location map can be made based on the selected grid themes. The present results can be integrated to select quantitatively the best potential sites for promotion of open sea farming.

Keywords: GIS, Remote sensing, Mapping, Site selection, Sea cage farming

AQ/O-5

Development of GIS model for shrimp farms at self governance level

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Geographical Information Systems are becoming an increasingly integral component of fishery resource management worldwide and play an important role in management and use of these natural resources. The shrimp farming being a vital income source for the coastal population in India, use of Remote Sensing and GIS can be looked upon as an emerging tool for management of these farms. So the information with regard to resource availability, resource use, information gap, constraints and potential areas need to be generated at local self governance level. In order to make the analysis of data more perceivable, interactive and easy to visualize, it is ideal to put it on GIS platform. Based on the source data, models can be created focusing the environmental issues, water resources and other topographic factors. It can be used as a tool for solving land allocation and land use between aquaculture and agriculture.

Geo-referencing of satellite data, overlaying the individual land parcel from cadastral map, digitization of individual land farms, and linking of secondary data on individual farms are the methodologies for the preparation of a panchayath level atlas of district. Other physical features such as settlements, rivers/channels, transportation network like roads, can be marked from the satellite data. The secondary data regarding the area, fish markets, nearby hatcheries etc can also be obtained by ground truthing. A graphical user interface can be designed on the basis of available information. This can be helpful in determining the suitable as well as potential areas for shrimp farming, management of the water body, identification and control of disease spread related to shrimps and scheduling the processing and marketing operations of shrimp products.

Keywords: Local self-governance level, Shrimp farming

AQ/O-6

Earth observation for global inland water quality monitoring and aquatic food security

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Surface waters are a fundamental resource. They fulfil key function in global biogeochemical cycles and are core to our water, food and energy security. The rapidly increasing rate of data collection from different Earth Observation (EO) missions suitable for observing water bodies has promoted satellite remote sensing (RS) as a more widely recognised source of information on a number of indicators of water quality and ecosystem condition at local and global scales. In parallel, advances in optical sensors support new and more detailed characterisation of the Earth surface and could lead to innovative EO-based products. Nonetheless, RS of water colour of inland and near-shore systems, especially in larger scales and over long-term time series, faces unique challenges such as temporally and spatially variable in-water optical conditions, continentality in atmospheric characteristics, complex shorelines and inconsistencies in satellite and vicarious calibration data collection. This presentation will describe the challenges and solutions of developing a global observation platform, including the diverse and complex optical properties of inland waters and guided algorithm selection procedure required to deliver reliable data. The development and validation of a global satellite data processing chain (Calimnos) has been supported by access to an extensive *in-situ* data from more than thirty partners around the world that are now held in the LIMNADES community-owned database. This approach has resulted in a step-change in our ability to produce regional and global water quality products for optically-complex waters. Local examples of the data outputs will be explored and the opportunities in how these data can be embedded within local and national monitoring schemes to facilitate better management of water will be discussed. This talk will also summarise our research and activities on RS in support of aquatic food security. While aquaculture and fisheries are of strategic importance to global food security, employment and economic growth, they remain highly vulnerable to external stressors with poor water quality and climate change foremost amongst current threats. We will show some results and case studies from H2020 TAPAS and CoastObs projects in developing (innovative) user-relevant EO products and enabling current aquatic resources to be used more efficiently.

Keywords: Remote sensing, Limnades, Food security.

AQ/P-1

Use of GIS and remote sensing in selected limnological aspects of Powai Lake

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In recent years, the Powai Lake has been strongly invaded by pollutants that lead to eutrophication. Large amounts of elements imported and used in the Powai Lake can easily enter aquatic systems and affect aquaculture. Domestic waste can be transported in the environment by chemo-dynamic procedures and hydrological processes. As a result, their residues in sediment, water and biota have been detected in the Powai Lake. This study investigated the effluent areas and evaluated the potential impact on aquaculture sites for some target aquatic species using Geographical Information System (GIS) and remote sensing tools concurrently with the conventional tools. Water, plankton, fish and sediment samples were collected during pre-monsoon, monsoon and post-monsoon on monthly basis. The results showed that accumulation of elements occurred at highest rate during pre-monsoon and post-monsoon. The spatial models showed that nutrient concentration was high in the Lake. The finding reveals that productivity of the Lake in term of plankton and nutrients varies with season of the year. This research indicates the potential relationship between the data obtained by GIS and conventional methods for aquaculture. The model has several significant uses such as providing information to policy makers for a more harmonized development for aquaculture in the Powai Lake, it provides data for aquaculture investment analysis to decrease the hazards caused by pollution, and it provides a model capable of application to wide field scenarios and suitable for both fresh and marine water.

Keywords: Aquaculture, Fish, GIS, Plankton, Powai Lake

AQ/P-2

Integrated resilience framework for fisheries and wetlands through aquaculture and geospatial monitoring

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Climate change has profound impacts on wetland ecosystem. The vulnerability of coastal wetlands has increased due to associated phenomena such as sea level rise, saline intrusion, floods, etc. As India have 5,55,557 small wetlands (<2.2ha) to enhance sustainability, the climate resilient strategies need to be aligned with focus on region specific small wetland management. This paper reports a wetland resilience framework integrated with key components as regional wetland mapping, GIS based portal, aquaculture and real time advisories. Spatial database of small wetlands at panchayat level could be created using remote sensing data, thereby enabling effective regional resource management. Geospatial analysis of the regional wetlands could be done in association with local self-governing bodies (LSGs). The ecological, hydro-biological and physico-chemical data of regional wetlands could be integrated to spatial database and the profile could be assessed for wetland health categorization and vulnerability prioritization. GIS based portal disseminates regional wetland information and thereby could be used by policy makers and stakeholders for enhancing wetland ecosystem functions. In order to attain regional nutrition security, the proposed means is the integration of aquaculture practice with stress tolerant fish species. Implementation of aquaculture techniques could generate quantitative periodical water quality data which along with qualitative data generated through remote sensing techniques could be integrated on to geoportal resulting in a comprehensive monitoring system. The scientific communities could process the wetland portal data to monitor and predict climate related and other threats or stressors such as floods, storm water influx, agricultural runoffs, pollutant discharge, drainage pattern, catchment area status, aquatic vegetation spread, land use, etc. on a regional basis and real time wetland advisories could thus be provided. Multi-tier monitoring system involving scientific institutes, NGOs and Self Help Groups (SHGs) has been envisioned in which competent scientific institutes and NGOs could evolve as regional monitoring centres (RMCs). The integrated framework that is suitable for rural as well as urban small wetlands facilitates regional wetland vulnerability assessment, wetland monitoring and sustainable resilience.

Keywords: Aquaculture, Climate change, Geospatial monitoring, Resilience, Wetland

AQ/P-3

Ecosystem effects of energy flows in a tropical reservoir through modelling approach

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The measurement of biomass flow, transfer efficiency, and dissipation of energy among the various ecosystem components can provide significant information on the trophic structure and function of the whole ecosystem. The algortithms used for such measurements are collectively known as network analysis and are derived from input-output, trophic and cycle analysis and estimation of system properties. Using ecosystem modelling approach the system network of Karapuzha Reservoir was mapped into a linear food chain which had five trophic levels. Karapuzha Reservoir in the Wayanad District of Kerala with a total water spread area of 1250 ha at Fuel Reservoir Level was impounded in 1979. In order to integrate available information on biomass, food spectrum and dynamics of the main species populations of the reservoir ecosystem, a network model of fifteen compartments which included the non- living group, detritus was constructed by the use of the Ecopath software. The results of the model give an overview of the resources found in the reservoir and reveal the degree of interactions. The mean trophic transfer efficiency was 7.4 %. Finns cycling index of 6.19 % of total system throughput and a mean path length of 2.71 were obtained. The total system throughput of the ecosystem was 30,039.665 t km^{-2} $year^{-1}$. The gross efficiency was lower for tilapia, minnows, eels and crustaceans because of the low quality/density of their preferred prey. It is generally much lower than 1.0. For the Karapuzha model, the value obtained was 0.194 indicating a fishery comprising fishes in the middle of the food chain. The high Production/Respiration (P/R) value (4.95) for Karapuzha reservoir indicates that the reservoir is not yet 'mature'. The total primary production / total biomass (P/B) value of 52.4 also shows that the ecosystem is in the developmental phase. The network summary statistics computed for the model suggest an overall picture of the Karapuzha Reservoir as a system of a low degree of maturity.

Keywords: Ecopath, Ecosystem modelling, Production/Respiration

AQ/P-4

Identification of potential mud crab farming sites in Ratnagiri district of Maharashtra, India using GIS and remote sensing techniques

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The State of Maharashtra has vast stretches of estuaries, creeks and mangrove swamps which offer great potential for aquaculture, particularly for mud crab farming. In view of the natural resources and market potential for mud crab, the Department of Forests, Government of Maharashtra aims to promote mud crab farming in the state of Maharashtra through a novel approach which aims to provide livelihood support to the local communities utilizing the mangrove wetlands; thereby the local communities also have the responsibility of conservation of mangroves. A study was conducted to identify suitable sites for sustainable mud crab culture in GIS environment, based on various physical and environmental criteria including topography, soil types, land-use systems, vegetation, water quality, water availability, salinity, risks of flooding, infrastructure, seed resources and availability, market and support services. The brackishwater stretches of Anjarle, Kelshi, Aade, Velas and Ansure in the Ratnagiri district of Maharashtra were studied and all study stations had patchy to thick mangrove vegetation and the major mangrove species encountered were *Avicennia marina*, *Avicennia officinalis*, *Sonneratia caseolaris*, *Rhizophora mucronata* and *Acanthus ilicifolius*. The pH of water was near-neutral to alkaline, while dissolved oxygen levels were found to be within the ideal range. The salinity of the tidal creeks ranged from 4.04 ppt (Kelshi) to 35 ppt (Ansure), which generally varies with the tide. The ammonia levels which ranged from 0 (Ansure) to 0.05 ppm (Anjarle), fall within the safe levels for aquaculture. The sediment pH ranged from 6.02 to 7.32. The organic carbon levels in sediment ranged from 1.26 to 2.61% indicating medium to high productive nature of sediment. Samples of mud crab collected from the study areas were processed for screening for WSSV infection. All samples gave negative results in primary as well as in nested PCRs, indicating the absence of WSSV in the wild mud crab population. Integrating the analysis result along with supporting spatial data with the aid of GIS and Remote Sensing techniques, a total of 10.063 ha has been evaluated as suitable areas for mud crab farming along the brackishwater stretches of Anjarle (1.91 ha), Aade (2.069 ha), Kelshi (1.77 ha), Velas (0.538 ha) and Ansure (3.776 ha).

Keywords: GIS, Maharashtra, Mud crab farming, Potential areas, Ratnagiri

AQ/P-5

Ecosystem based spatial approaches towards sustainable development of mariculture

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Ecosystem approach to aquaculture (EAA) is an alternative model of aquaculture development that not only brings the technical aspects of ecosystems design and ecological principles to aquaculture but also incorporates at the outset social ecology, planning for community development, and concerns for the wider social, economic, and environmental contexts of aquaculture. Using spatial approach in EAA, the potential of mariculture can be estimated spatially in terms of the intensity of its practice at a national level as mariculture production per kilometre of coastline length, thereby providing a contrast with the total fish production of the country. With regard to estimating potential, spatially defined frameworks are necessary for a common understanding of where and at what pace mariculture can develop. A pragmatic set of spatial frameworks, one for each species to culture system combination, integrate a variety of criteria that are fundamental to development, and based on the limits of current mariculture practice, can be developed. The criteria should include technical, economic and culture conditions. The main considerations for estimating mariculture potential regardless of the size of the location are: (i) sites which are technically and economically feasible to install cages, (ii) areas that promote good growth and high survival rates of cultured species and (iii) sites which have minimum interference or competition with other activities in the sea. The technical and economic feasibility has to be spatially integrated by identifying areas with optimum depths for cages (5-20 m), having current velocity ranging from 0.1 to 1.0 m s-1, that are within a distance of 5-10 km from a harbour facility. Potential, zoning and siting for aquaculture are all development activities that, ideally, follow a temporal and spatial progression beginning with estimating potential and ending with site selection. Carrying capacity has to be considered at all stages and scales of development and management, but is usually most thoroughly analyzed in conjunction with siting. The amount of activity directed towards estimating potential, zoning, siting and determining carrying capacity that has involved the use of spatial tools (GIS, remote sensing and mapping) can be measured in an indicative way by the applications in aquaculture. The best example of EAA, Integrated multi-trophic aquaculture (IMTA) is often based on recycling or eco-cyclic production, and has the potential to be more in tune with the processes and functions of the supporting marine ecosystem. The spatial domain of carrying capacity and site selection in mariculture extends from global to local, and is essential to estimate the potential for mariculture development and zoning of areas for mariculture and to be added to site selection and carrying capacity to make all essential tasks that are at the same time important spatial and temporal issues in EAA based mariculture.

Keywords: EAA, Mariculture, Ecosystem

Session-5

Harvest Fisheries

HF/O-1

Spatial model derived Potential Fishing Zone delineation in the northern Bay of Bengal near West Bengal coast

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Oceans are globally recognized as the abode of several natural resources out of which fishes are of prime importance. The distribution and availability of fish stock in the oceans primarily depend upon the availability of food and conducive climate. Potential Fishing Zones (PFZs) are those regions where the fishes aggregate due to abundance of food. These regions are identified by co-existence of sharp Sea Surface Temperature (SST) gradient along with optimal chlorophyll-*a* (Chl-*a*) concentrations. Accordingly, Indian National Centre for Ocean Information Services (INCOIS) has been disseminating the daily PFZ forecasts to the fishermen for fishing in the Bay of Bengal and Arabian Sea with an aim to provide the specific location of probable fish aggregation. This actually minimizes the fuel consumption and scouting time. A similar regional spatial model derived PFZ has been developed in the present study for the West Bengal coast. Cloud free MODIS L2 SST and chlorophyll data of 1km spatial resolution for two consecutive winter seasons of 2015-16 and 2016-17 were used for developing the PFZs. The pixel values from both the SST and chl-*a* were extracted along the shape files of INCOIS PFZs. The histogram ranges of the extracted SST and chl-*a* were selected based on two criteria, one is the amplitude and another is the span of the peaks. Subsequently the same values lying within both the SST and chl-*a* images were also extracted using a spatial model in ERDAS Imagine. After obtaining the modeled SST and chl-*a*, overlay analysis were performed to get their convergence points. These points were then connected with lines depending on their proximity with the SST gradient.The model derived PFZs were then validated with the ground data on fish catch. A substantially good fish catch was observed in the model derived additional PFZs predicted outside the INCOIS advisories. The catch per unit effort (CPUE) values were very close to the predicted CPUE of INCOIS PFZ advisories. However, the CPUE values in the non-PFZ areas were significantly lower than the former two categories.

It is observed that this method developed along the same line of logic for potential fishing zone estimation is valid mostly for pelagic fishes but cannot be applied for *Hilsa* as they take negligible amount of food during their breeding migration to fresh water estuaries during monsoon where satellite availability is limited.

Keywords: Chlorophyll, SST, CPUE, PFZ, Spatial modeling

HF/O-2

Applications of remote sensing in predicting the abundance of ribbonfish *Trichiurus lepturus* along northwest coast of India

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Remotely sensed parameters like sea surface temperature (SST) and euphotic depth (Zeu) are used for predicting the abundance of *Trichiurus lepturus* along the north west coast of India. Daily and weekly level 3 images of SST, chlorophyll-*a* (chl-*a*) and diffuse attenuation coefficient (K_{490}) derived from the Aqua Moderate Resolution Imaging Spectroradiometer (Aqua-MODIS) Satellite for the period March 2013 to December 2014 were acqured. K_{490} and Chl-*a* images were used to model the euphotic depth for inshore and offshore waters respectively for the study area, to investigate the relationship between SST and Zeu to the *T. lepturus* abundance. The study revealed that the most favourable range of SST was 27.5 to 29.5°C and euphotic depth was 30 to 60 m for the better abundance of *T. lepturus*. Significant positive correlation was observed between independent parameters (SST and Zeu) and the dependent parameter *i.e.*, abundance of *T. lepturus* ($r^2=0.608$, $p<0.05$). The predicted abundance of *T. lepturus* in connection with SST and Zeu was found to be 61% accurate along the study region. This study depicts that the integration of remote sensing and GIS technology with statistical model may be useful to predict the abundance of *T. lepturus*. This may contribute in decision making on fishing grounds and reducing scouting time for fish catch and input cost in the fishing activities.

Keywords: Euphotic depth, Remote sensing, SST, Fish abundance model.

HF/O-3

Biogeochemical modeling in complementing satellite-aided operational marine fishery advisories

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Utilizing the remotely sensed Sea Surface Temperature (SST) and sea surface chlorophyll (Chl-*a*) data retrieved from various satellites, ESSO-Indian National Centre for Ocean Information Services (INCOIS), provides Potential Fishing Zone (PFZ) advisories to the fishermen on a daily basis. Sometimes it becomes a major challenge to retrieve Chl-*a* data from satellite images, particularly during periods of extensive cloud coverage. This study aims to demonstrate how a biogeochemical model simulated Chl-*a* and SST can be used in complementing spatio-temporal gap-free generation of operational PFZ advisories in the surface waters of the northeastern Arabian Sea. We compared ocean features (upwelling, eddies, gyres etc.) extracted from high-resolution chl-*a*/SST data retrieved from MODIS-Aqua satellite against the features extracted from Chl-*a*/SST data simulated using Regional Ocean Modeling System (ROMS) bio-physical model during the northeast monsoon (October 2016 to January 2017). In comparison, the model simulated Chl-*a*/SST data are capable of producing ocean features as observed from satellite data. However, the model is found to be capable of producing large scale features better than the smaller scale features. It is also observed that ocean features are more vibrant in modeled Chl-*a* than modeled SST, which could be due to vigorous winter convective mixing leading to high Chl-*a* in the northeastern Arabian Sea during the northeast monsoon. As the ocean features observed from model simulated gap-free data are well in agreement with the ocean features observed through satellite data, modeled Chl-*a* and SST can be used in complementing the continuous generation of marine fishery advisories.

Keywords: Chlorophyll-*a,* MODIS-Aqua, PFZ, ROMS, Temperature

HF/O-4

Bio-optical characterization of coastal waters using ocean colour data for fishery applications

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India has a long coastline of around 7500 kms and fishery is one of the major industries in coastal regions of India employing around 14 million people. The ocean colour remote sensing plays a vital role in fishery applications. Bio-optical parameters like chlorophyll-*a* (Chl-*a*), coloured dissolved organic matter (CDOM) and particle backscattering (bbp) of the marine waters are important to characterize the environment for fishery applications from satellite data. Considerable success has been achieved in optical remote sensing of Case-I open ocean waters, where the variation in optical properties is dominated by phytoplankton and associated material. On the contrary, ocean color remote sensing over Case-II waters such as coastal and estuarine waters becomes difficult, where the optical properties of inorganic suspended matter and CDOM modulates the light field. The present study deals with remote sensing estimation of bio-optical parameters from ocean colour sensors with special emphasis on Oceansat-2, OCM data using Garver Siegel Maritorena (GSM) model in coastal regions. In this study, non-linear optimization technique of Levenburg-Marquardt (*LM*) has been used to retrieve Chl-*a*, CDOM and *bbp* of the coastal waters. The ease of this technique is that it incorporates two methods, Gauss-Newton method and steepest descent method for minimization of errors in a least square sense on an iterative basis. GSM model was applied to *in-situ* reflectance data from Chennai coastal waters to retrieve Chl-*a*. When compared with *in-situ* measured Chl-*a*, the model explained the variability in the dataset with coefficient of determination (R^2=0.81) and a root mean square error (RMSE=0.22). The model was applied to Oceansat 2-OCM data to retrieve bio-optical parameters. The results are compared and discussed.

Keywords: Chlorophyll-*a,* CDOM*,* Particle backscattering

HF/O-5

A synergistic approach based on remote sensing and ocean model simulations to identify and track Potential Fishing Zone for the Bay of Bengal

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A new method has been proposed to identify and track the Potential Fishing Zones (PFZ) in the Bay of Bengal waters. A limited validation has been carried out for the period January-March 2017. The method is built on ocean features derived from satellites and numerical model simulations. The method is primarily based on oceanic features, like thermal front and mesoscale eddies. The AVISO altimeter based Sea Level Anomaly (SLA) weekly data has been processed to analyse and identify the cyclonic and anti-cyclonic eddies based on the sea surface height anomaly greater than +5 cm amplitude. The positive anomaly features are considered to be cold core and negative anomaly features considered to be warm core eddies. Correspondingly non-eddy zones are also identified in the study area. The identified eddies and non-eddy regions have been linked to the GHRSST based Sea Surface Temperature (SST) gradients and frontal zones during the week. The SST contours have been overlaid on the eddies and non-eddy zones. To link to ocean biology and productivity, the Oceansat-2 OCM and Globcolor merged product chlorophyll images have been processed; the high and low concentration features and patches have been collocated around the SST gradient contours along the eddy and non-eddy regions. To correlate the above features with ocean surface wind and currents, the relative wind has been calculated using the SCATSAT-1 wind speed and ocean model simulated surface currents datasets. The SST frontal vector has been linked to the relative wind vector, to calculate the up-front, down-front and cross-front wind. If both frontal and wind directions are aligned, it is observed that intensity of thermal front increases and a drift of front is observed almost along the resultant vector as shown in Figure 1. The frontal wind direction has been linked to the chlorophyll patches. Attempt has been made to understand the probability of PFZ and its persistence with the lag time period using the current approach. The method holds good promise, however needs to be verified extensively with the geo-tagged fish catch data for proving its robustness.

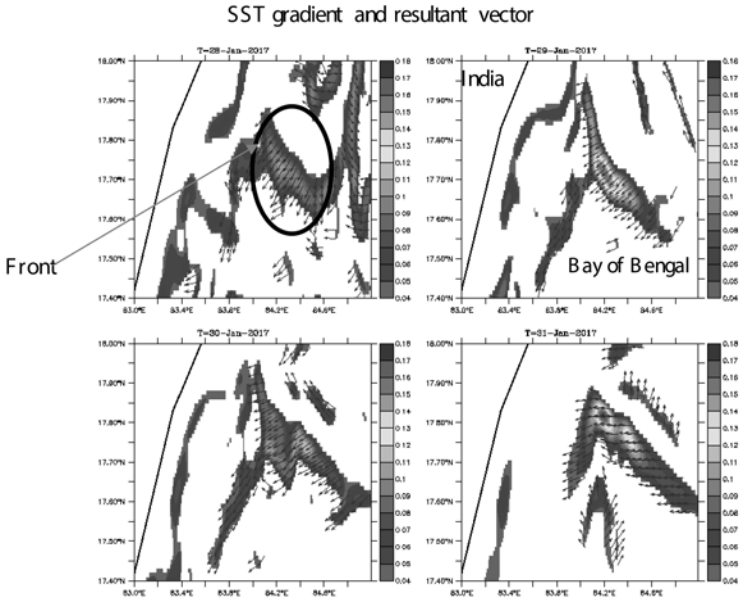

Figure 1: SST gradient and resultant vector for the period 28-Jan-2017 to 31-Jan-2017.

Keywords: PFZ, SST, Eddies/ Bay of Bengal

HF/O-6

Harnessing high temporal resolution data from geostationary orbit for marine fishery predictions

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Since inception of PFZ (Potential Fishing Zones) application of satellite remote sensing at ISRO, and its establishment as an operational ISO-certified service to INCOIS, only data from polar-orbiting satellites (POS) have been used. Initial attempts at INCOIS to use geostationary satellite (GS) SST (Sea Surface Temperature) data (e.g. Kalpana-1) faced difficulties due to coarse 8 km spatial resolution. Another opportunity has arisen after launch of INSAT-3DR mission in September, 2016. Along with its predecessor INSAT-3D mission, SST data at 4 km spatial resolution is now being made available for every 15 minutes – for full disc (the Indian Ocean region). Efforts are underway to harness these data and establish an SOP (standard operating procedure). We present here the primary results of successful PFZ identification, as a part of these. The GS data not only helps

in filling gaps in the POS data, but also provides opportunities for value-added services such as PFZ *NOW*cast – paving the way for future use of SST and ocean colour data from GS platforms.

Keywords: Geostationary, Polar-orbit, PFZ, SST

HF/O-7

Studies on the correlation between satellite derived SST and yellowfin tuna catches through long line off the Andhra Pradesh coast

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This study investigates the relationship between yellowfin tuna (*Thunnus albacares,* YFT) caught off the Andhra Pradesh coast by the mechanised long line fleet and environmental variables mainly, Sea Surface Temperature (SST) remotely sensed by Advanced Very High-Resolution Radiometer (AVHRR). The satellite SST data used for the present study were recorded by AVHRR sensor onboard the National Oceanic and Atmospheric Administration (NOAA) satellites (N-18, N-19) and the European Space Agency satellites (MetOp-A and MetOp-B) and were acquired from satellite data-reception ground station at INCOIS, Hyderabad. The Catch per unit effort (CPUE) was calculated as the number of fish caught by 1000 hooks for the period 2012-2014. Results showed multi modal distribution of catch yields across the SST values. While most catch records of YFT during the study period were in the Monthly Mean Sea Surface Temperature (MMSST) range of 24.5˚C and 29.5˚C, abundant catches were obtained in the areas where MMSST ranged between 24.5-26.5˚C and between 27.5-29.5˚C. The Mean temperature of the sea water recorded was 27.53˚C with a standard deviation (SD) of 1.34 during the study period. This study also documented the long line resources and the variation in long line fishing off Andhra Pradesh coast.

Keywords: Long line, Yellowfin tuna, Remote sensing, Andhra Pradesh coast

HF/O-8

Optimal spectral bands for chlorophyll-*a* algorithm towards better prediction of fisheries along Indian coast using satellite remote sensing

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Fishery resource exploration in the sea has gained large attention due to its socio-economic values. With advancement in the technology, satellite remote sensing products have been efficiently used to detect the fishery resources in the sea. The Sea Surface Temperature (SST) and chlorophyll-*a* (chl-*a*) are the critical parameters providing information on physical (fronts and eddies) and biological processes (primary productivity) and hence used for identifying potential fishery resources. Most of the fishery resources are confined to the coastal waters where the accuracy of the bio-optical algorithm for detection of chl-*a* is limited due to interference of signals from other optically active substances (OAS) such as Coloured Dissolved Organic Matter (CDOM) and Total Suspended Matter (TSM). The present study intends to develop bio-optical algorithm to estimate chl-*a* from optically complex Indian coastal waters by selection of optimal wavelengths using derivative analysis. Total 191 quality checked *in-situ* hyperspectral Remote Sensing Reflectance (Rrs) data were analyzed. Based on spectral variability of Rrs, Indian coastal waters were classified into four water types. The geographical distribution showed that Type-1 water was farthest (38±21 km) whereas Type-4 water was closest (6±3 km) to the coast, indicating that the source of OAS is from land discharge and / or coastal processes. The second order spectral derivatives of Rrs showed 12 common peaks (415, 440, 465, 490, 515, 530, 550, 570, 600, 650, 665 and 685 nm) in all the four water types, having optimal impact of chl-*a* on Rrs in the presence of other OAS. The maximum band ratio based bio-optical algorithm was developed relating Rrs with Chl-*a*. The new algorithm provided better estimation of Chl-*a* with high correlation coefficient (R^2=0.92), slope (0.9), low intercept (0.02) and Root Mean-Square Error (0.12), as compared to standard algorithms, making it efficient to use in optically complex Indian coastal waters.

Keywords: Algorithm, Chlorophyll-*a* derivative, Remote sensing reflectance, Water types

HF/P-1

‘Drought in the sea’-sardine habitat changes in the southeast Arabian Sea - the reasons and the consequences.

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The coastal upwelling zone off Kerala is one of the major habitats of the Indian oil sardine, *Sardinella longiceps*. The oil sardine fishery which supports the livelihood of coastal fisher families, has seen wide inter-annual fluctuations during the last 116 years. In the current decade, the sardine fishery of Kerala declined to 46,000 tonnes in 2016 from an all-time peak of 3.99 x 10^5 tonnes in 2012. The reasons for decline in sardine fishery were found to be due to fishery dependent and independent factors. It was observed that the sardine habitat temperature had increased and the phytoplankton density decreased in 2015. This inference based on real-time observations was considered as a ‘drought like situation in the sea’. An analysis was done to find out whether these changes were reflected in the remotely-sensed SST and chlorophyll-*a* data pertaining to this region and the results are presented here.

The analysis indicated that high SST prevailed in the sardine habitat during 2015. The average SST was 28.6 $\pm$0.18ºC during 2003-2014. The SST in 2015 ranged between 30.2ºC and 28.1ºC with an average of 28.09ºC indicating a difference of 0.49ºC. Similarly, chlorophyll-*a* data from satellite which gives an indication of the food available for the sardine was also considerably low, (0.27 mg m^{-3}) compared to 2003-2014 period (0.47 $\pm$ 0.09 mg m^{-3}). This combination of high SST and low food supports the real time observations and can be considered as short term drought in the coastal waters.

Sardines are planktivorous with high preference to diatoms as food. The gut content analysis of sardine caught from off Kochi fishing area were analysed. The results indicated that guts were either ‘empty’ or only ‘one fourth full’ during the period 2015. ‘Gorged’ gut as observed during the previous years were not seen in the samples analysed. This also indicates that “drought’ like situation affected the sardines.

The results of the analysis to assess links of such a stressed situation with ocean atmospheric processes like MEI and IOD and the data on gut content of sardines along with phytoplankton densities of the sardine habitat are presented. The paper also proposes the term ‘Oceanic Drought’ to indicate the condition like above normal SST

and below normal chlorophyll-*a* in the ocean leading to less than normal fishery yield. The study indicates the need to develop prediction models for sardine fishery and the need to manage the sardine stock from overexploitation.

Keywords: *Sardinella longiceps,* SST, Phytoplankton, Oceanic drought

HF/P-2

Predictive changes and catch forecast of Indian marine fisheries

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Climate change has far reaching influence on marine fisheries because of the direct exposure of marine fish to climate variables as well as a range of direct and indirect ecosystem responses to climate change. Climate variability affects the spatial and temporal distribution, patterns of migration, diversity, abundance, reproduction and recruitment of economically important marine species. Predictive changes in climatic variables such as Sea Surface Temperature (SST), Sea Surface Salinity (SSS), Sea Level Rise (SLR), chlorophyll (Chl) and precipitation (Pr) were done using the MIROC-ESM-CHEM model from CMIP5 for 2030, 2050 and 2080 for four RCP scenarios 2.6, 4.5, 6.0 and 8.5. Despite the availability of scientific evidence regarding climate change, it is very critical to obtain how the climate change variability can influence the marine fish catch. So the decadal trends of climate change with catch data were correlated. Using the model output the catch forecast were done for 2030, 2050, and 2080 along Indian coast. The inferences from projected changes in oceanographic variables along with vulnerability prediction and catch forecast may help for developing possible adaptation strategies.

Keywords: Catch forecast, Climate change, Oceanographic variables

HF/P-3

Impact of decadal changes of oceanographic variables on Indian marine fisheries

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Climate change induces several impacts on the marine ecosystem, which is one of the most productive ecosystems in the world. The changes in oceanographic variables such as Sea Surface Temperature (SST), pH, Salinity, Chlorophyll concentration, Rainfall

and Sea Level Rise were assessed for a decade of 2007-2016. Impact analysis of each parameters on prioritized marine species as per the vulnerability assessment were done along Indian coast and specifically on four coastal zones. The decadal climatic variations were correlated with fish catch data of SW, SE, NW, and NE of highly vulnerable species. Sea Surface Temperature over the Indian Ocean shows an increasing trend whereas pH and Chlorophyll concentration shows a decreasing trend. This changing trend seems to have impacts on Indian marine fishery, which has led to a reduced catch of several commercial fishes over a period of time. The impact identification helps in effective development of mitigation and adaptation strategies for Indian marine fisheries sector. Further this calls for a detailed study on the future projections of environmental variables to foresee better adaptation strategies for sustainable development of marine fisheries.

Keywords: Oceanographic variables, Indian marine fishery, SST, Chlorophyll concentration

HF/P-4

Variation of chlorophyll-*a* concentration in Vietnamese sea by MODIS data and its relationship with fishery

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Phytoplankton biomass (or chlorophyll-a concentration, Chl-*a*) plays a vital role in the marine ecosystem as food for marine fish. Thus, the variation of chlorophyll-a concentration lead to change in fishery in Vietnam sea. Based on processed MODIS images combined with *in-situ* data to extract Chl-*a* concentration during the period of 2003-2015, the variation of Chl-*a* and its relationship with fishery in Vietnamese sea was studied. The local empirical coefficients of algorithm OC3 to estimate Chl-*a* concentration at the surface were determined. The variation of Chl-*a* concentration both in space and time indicated that three seasonal upwelling regions, namely, southern center of Vietnamese waters, northeastern waters of Hainan island in summer, and northwestern Borneo in winter, showed peaks of Chl-*a* concentration in 2004, 2007, 2009 and 2011. Study in relation to fishery abundance showed that increase in monthly and annual Chl-*a* concentration could help in subsequent increase in fishery but with a lag time of 3-5 months. These results can help in predicting fishing grounds by the phytoplankton biomass in marine regions.

Keywords: MODIS, Chlorophyll-*a*, Fishing ground, Vietnam

HF/P-5

Insight on Potential Fishing Zones persistence in the southern Tamil Nadu, India

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Potential fishing zone (PFZ) advisory maps of Indian National Centre for Ocean Information Services (INCOIS) are the remotely sensed satellite derived imageries of locations with special oceanic processes (SOPs) that are considered as biologically productive. The advisories serve as a proxy for the fish shoal aggregation. An analysis of 260 PFZ advisories maps of south Tamil Nadu was performed for two years from November, 2015 to October, 2017 to elucidate the persistence and possible spatio-temporal relationship with geo-coordinates & bathymetry. For the ease of understanding, the Indian EEZ fishing areas were divided into seven zones (one degree grid) and further sub-divided into 16 grids from Gopalapattinam of Pudukkottai to Neerodi of Kanyakumari waters. The analyses clearly indicates that PFZ hits (SOPs indicated as curved line marking on the advisory chart) was more between 8 to 9° N Latitude and 78 to 79° E Longitude off Thoothukudi waters followed by off Kanyakumari waters between 7 to 8° N Latitude and 77 to 78° E Longitude. The results of bathymetry grid plotting showed that high frequency grids were in the mid continental shelf region (50 to 200 m; 44.9% of the total PFZ hits) followed by the near shore (<50 m; 31.4%) and the continental slope (>200 m; 25.1%) regions. The study revealed that upto 200 m, the frequency of occurrence of PFZs increase with increase in depth and beyond 200 m, the frequencies started decreasing. The number of PFZ advisories were high during August to December ranging between an average of 12 to 18 per month, followed by January and February (with an average of 7 and 10 per month). The result also revealed that area persistence of PFZ was more along Thoothukudi waters and this might be due to the discharge of nutrients from Thamirabarani River at Punnakayal estuary during onset of northeast monsoon season (NEMS). Further, the East India Coastal Current (EICC) in the western Bay of Bengal that flows equatorward and transports low saline waters into the Arabian Sea also makes the Kanyakumari waters productive in addition to the nutrient flux from various freshwater bodies.

Keywords: INCOIS, PFZ, Remote sensing, Spatio-temporal relationship, Validation

HF/P-6

Seasonal variability of PFZ formation: A case study from northwest coast of India

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The Potential Fishing Zone (PFZ) advisory generated using satellite-based remote sensing data is a boon to the marine fisher folk and usefulness of it in fishing activity is increasing progressively. ESSO-INCOIS is the nodal agency to provide the PFZ advisory on daily basis with specific reference to 586 fish landing centers along the Indian coast. ESSO-INCOIS utilizes the Sea Surface Temperature (SST) data retrieved from NOAA-AVHRR, and Chlorophyll from OCEANSAT II and MODIS Aqua for the detection of PFZ along the Indian coast. The PFZ is a method to identify the prospective fishing areas based on special oceanic features such as eddies, rings, oceanic fronts, meandering patterns and upwelling areas using satellite data. The present study was undertaken to understand the seasonal and spatial variability of PFZ along Maharashtra during 2012 to 2015. The PFZ advisory provided by INCOIS during 2012-2015 were utilized for digitizing the PFZ database. GEBCO bathymetry data was utilized for depth analysis. Fishnet tool was used to create grid along off Maharashtra from latitude 20º to 16º N and longitude 73º63' to 69º63'E and to extract depth corresponding to subgrid. The digitized PFZ data was overlaid on a grid to record PFZ in each sub-grid. PFZ line passing over sub-grids was considered as occurrence of PFZ in sub-grids. The total number of PFZ occurrences in each sub-grid was summed up for each month. The grid was divided into 24 zones (one degree) further subdivided into 16 sub-grids. Based on depth, the area was categorized into three divisions viz., near shore (<50 m), mid continental shelf (50-200 m) and continental slope (> 200 m). The seasons were divided into three categories-monsoon and fall intermonsoon were considered as one season (FIM; August-November), winter monsoon (WIM; December-February) and spring intermonsoon (SIM; March to May). Analysis of PFZ advisory during 2012-15 along the Maharashtra coast revealed that the mid continental shelf area has a frequent occurrence of PFZ (n=2905, 46%) comparative to the area along the near shore (n=1759, 28%) and continental slope (n=1704, 27%). Seasonal comparison showed a definite pattern of PFZ occurrence, the highest occurrence of PFZ was 46% during WIM: it may be associated with winter cooling and convective mixing. PFZ occurrences during FIM and SIM were less by 24% and 30% respectively.

Keywords: Depth, Occurrence, PFZ, northwest coast

HF/P-7

Marine, Coastal & Fisheries climate projections - a combined EO and model approach

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Climate change will have significant impacts upon marine and coastal ecosystems, affecting resources such as natural fisheries, aquaculture and services such as tourism. For example:

- Changes in the spatial distribution of species habitats resulting from the co-occurrence of climate related stressors (warming, acidification, hypoxia) and ecosystem properties that support species persistence under climate change (*i.e.* productivity) will affect the distribution of fishing stocks and their biomass;

- Changes in the distribution of ocean fronts will modify productive fishing zones.

PML is leading a Europe-focussed project on behalf of the Copernicus Climate Change Service (C3S) that provides model-predictions of likely spatial and temporal distribution of changes based on a number of IPCC climate projections. A range of environmental indicators such as temperature and salinity from down-scaled regional simulations (CORDEX) are used to drive a biogeochemical model (ERSEM) yielding a further set of climate impact indicators (CIIs) such as primary production. Satellite observations are used to validate the system hindcast outputs. These CIIs are used to drive fisheries model SS-DBEM yielding fisheries information such as species distributions and stock levels.

Armed with these indicators, we are able to provide high impact solutions for engaged stakeholders including policy-makers, regulators, international entities, and fisheries & aquaculture companies, with the goal of enabling informed planning and effective management of fish stocks and long-term marine ecosystem conservation. Among the use cases to be outlined in the presentation, a unique approach, after Queiros et al. (2016) combines CII and GIS sectorial data analysis to communicate these results to regulators such as the UK Department of Environment, Food and Rural Affairs to facilitate Marine Spatial Planning.

This study will outline the key steps in the approach, how this could potentially be expanded to global areas of high impact, e.g. the Indian Ocean, and the advantages to the local marine sector through participation in the regional application of this system.

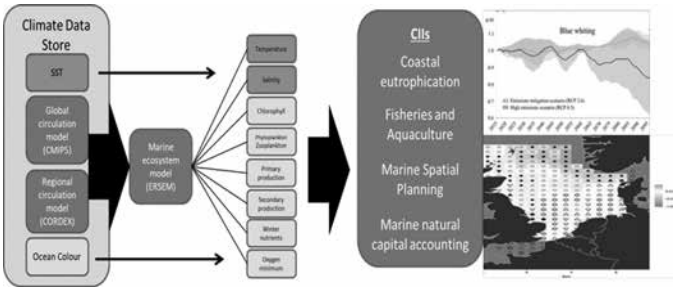

Figure 1: Marine, Coastal & Fisheries system overview; example regional stock projection; example MSP projection.

Keywords: CORDEX, ERSEM, Regional Simulations

HF/P-8

Prediction of the effects of rise in Sea Surface Temperature on population biomass of three resources for the hotspot region in southwest coast of India

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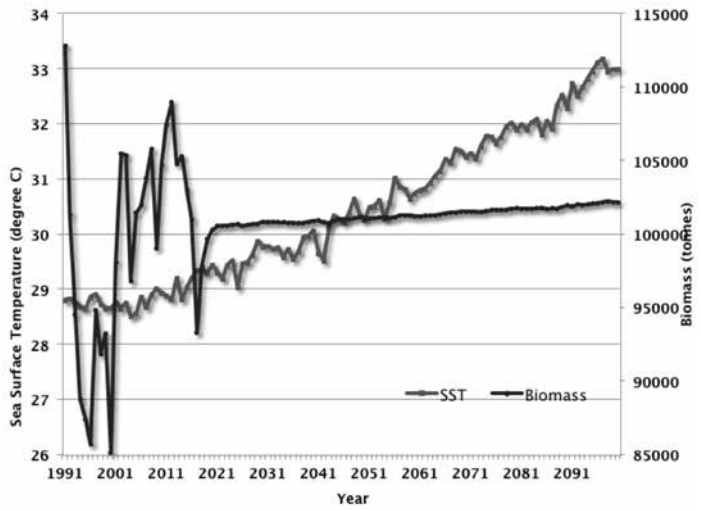
The southwest coast region comprising the coastal districts Trivandrum, Kollam, Alappuzha and Ernakulum in Kerala state is one among many hotspot regions globally identified as locations predicted to warm substantially faster than the global average. This region is highly productive and diverse in respect of marine fish harvest with landings of more than 270 species every year by mechanized, motorized and non-motorized fishing crafts. A population of about 3.4 lakh marine fishermen solely depend on marine fisheries for their livelihood. It is important to examine the changes that have happened in the composition and dynamics of marine fisheries resources landed in this region and its relation to climate change. The effect of climatic variations over years on the fishery of this region was evaluated for three major resources harvested from this region by modelling the dynamics of the biomass of the resources using time series data on fish catch and fishing effort and impact of climate change was examined by incorporating time series data on sea surface temperature in to the model. The resources examined

are lesser sardine, Indian mackerel and penaeid prawns. . The average landings of these resources in south Kerala region during the period 1991-2016 are lesser sardine 9163 tonnes, Indian mackerel 29,022 tonnes penaeid prawn 24,243 tonnes. The procedure adopted is a multi-species multi-gear modelling approach using information on annual landings of these resources during 1991-2016, separately by mechanized, motorized and non-motorized fishing gears along with fishing effort and satellite derived average sea surface temperature for the region.

The model used is a modified version of SEAMICE model. Maximum sustainable yield for the three resources were estimated based on the final model for each resources. The models fitted using fish catch, fishing effort and sea surface temperature revealed that in the case of lesser sardines the expected average percentage increase in its biomass in the south Kerala region when the sea surface temperature increased by one degree centigrade is 3.2%. Similarly for Indian mackerel biomass in the region the expected average percentage increase when the SST increases by one degree centigrade is 0.2% only. For penaeid prawns it is found that the expected average percentage reduction in its biomass in the region when the SST increases by one degree centigrade is as high as 53.5%. Plots of the observed catch, catch rate, expected catch, expected catch rate and estimates of biomass for the three resources are also given.

Keywords: Prediction, SST, Hotspot, Southwest coast of India



Plot of biomass estimates of lesser sardines and projected SST for the south Kerala region when the fishing effort is kept constant

Session-6
Fisheries Management

FM/O-1

A study on yellowfin tuna *Thunnus albacares* distribution along north Andhra Pradesh coast using Generalized Additive Models

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Yellowfin tuna, *Thunnus albacares* is a commercially important species of tuna which forms a lucrative fishery along the northern Andhra Pradesh coast of India, bordering the western Bay of Bengal. The fishery is mainly carried out by fishermen operating motorized hook and line vessels off the village of Pudimadaka, northern Andhra Pradesh. Very little is known about the distribution and the factors that influence the distribution of this species of tuna in the Bay of Bengal. Hence a study of the distribution of yellowfin tuna was carried out using fishery and oceanographic data and Generalized Additive Models (GAM) to identify the major factors which influenced tuna distribution in the fishing ground. Fishery data was collected from fishermen on a weekly basis during 2014-2016. Details were collected on catch (kg), mean size (cm), distance (km) and direction of fishing from Pudimadaka. Using the collected information, the catch positions were estimated and used to plot the fishing ground for yellowfin tuna. For the catch locations, sea surface temperature and Chlorophyll-*a* values were extracted using SeaDAS 7.4 software from the Level 3 binned AQUA-MODIS data products. The modified bathymetric data from NIO was used for depth measurements of catch locations. A Generalized Additive Model (GAM) was fitted using yellowfin tuna catch data as the independent variable and month, latitude, longitude, sea surface temperature, Chlorophyll-*a* and depth of area as the predictor variables. The final model with the best fit could explain 52.5% of the fluctuation in the catch values. Month of fishing, latitude and longitude were the only significant parameters in the model indicating that there were strong spatial and seasonal influences on the distribution of yellowfin tuna along northern Andhra Pradesh.

Keywords: Andhra Pradesh, AQUA-MODIS, Generalized Additive Models, Yellowfin tuna

FM/O-2

Resource mapping of fishing systems of estuaries in Maharashtra

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Estuaries support the sustenance of marine fishery resources, as the life cycle of many marine fishes has an estuarine phase. There are six maritime districts located along the Maharashtra coast, each having several minor creeks and estuaries emptying into the Arabian Sea. Study on fishing systems and fisheries resources of Karanja and Bhayander estuaries, two important estuarine ecosystems located in the Raigad and Thane districts of Maharashtra respectively was carried out between September 2016 to May 2017. Dol nets and gill nets were the major fishing gears operated in these estuaries that supported the livelihood of fishers of these villages. The mesh size of dol nets operated in these estuaries varied from 8 mm at the cod end to 165 mm at the mouth. Major catch in dol nets comprised *Acetes indicus*, *Harpadon nehereus*, *Coilia dussumieri*, *Lepturacanthus savala* and *Parapenaeopsis sculptillis*. In the Bhayandar estuary, gill nets of 70 to 90 mm mesh size were operated. Lobsters, croakers, pomfrets, seer fishes and catfishes were the major contributing species in gill nets. Gill nets were operated seasonally for harvesting lobsters and catfishes whereas the operation of dol nets was observed throughout the year. Significant discards such as jellyfishes, juveniles of several fishes and plastics were recorded in the dol nets operated in the Karanja estuary. Thematic maps of selected fishery resources, fishing locations, discards, plastics and catch were prepared by using Arc GIS 10.2 software. As very little information is available with regard to fisheries resources and fishing systems of estuaries, information on design, catch composition and fishing operations of gill net and dol net along with thematic maps would be helpful for the managers to optimise fishing operations in the estuaries of Maharashtra.

Keywords: Dol net, Estuary, Gill net, Maharashtra

FM/O-3

Decoding the discontinuous distribution of *Harpadon nehereus* (Hamilton, 1822) using satellite data

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Harpadon nehereus (Family Synodontidae) is a commercially important fish species in the Indian Ocean region. It is popularly known as Bombay duck and is widely distributed along the coasts of East Africa, Indian subcontinent, Burma, Malaysia, Indonesia and South China Sea. This fish is also called as 'surprise fish' because it shows 'discontinuity' along the range of its distribution. Along the African coast, it is reported only from Zanzibar. It is harvested in very low volumes along the coast of Sind province of Pakistan. In Indian waters, *H nehereus* is found along the coast of Gujarat and Maharashtra down south up to Ratnagiri coast, also along the Odisha and West Bengal coast along the eastern side. The fish is not available along the southwest and southeast coasts of Indian sub continent. Bombay duck is fairly harvested from Bangladesh and Myanmar waters but has not been reported from the Thai waters. The records of Bombay duck are also available from Malaysia, Indonesia and up to South China Sea. Though this fish is vastly distributed, it forms a major fishery along northwest Indian coast. During 1999 India contributed to about 92% of the world Bombay duck landings. Many workers have attempted to explain the discontinuous distribution by relating the discontinuity to oceanographic and geographic parameters. Availability and abundance of Bombay duck has been correlated with the distribution and movement of favorite food; oceanographic parameters such as Sea Surface Salinity (SSS), Sea Surface Temperature (SST), isotherm of 26.7° C during July months; geographic structures such as estuaries, presence of islands and river runoff. However a clear idea on what environmental parameters or geographic structures are responsible for discontinuous distribution is lacking. Today, due to advent of technologies such as Satellite Remote Sensing (SRS), *in-situ* data from ocean buoys and powerful softwares, this phenomenon can be studied in a synoptic way. Oceanic and climate parameters such as SST, SSS, dissolved oxygen, ocean currents, winds, rainfall, river runoff *etc.* can be derived from satellite data. Such information can be used to locate the areas of Bombay duck availability, and the influence of oceanographic or geographic parameters acting upon the distribution of Bombay duck, individually or in combination. With the help of these techniques and data sources, we would be able to decode and understand the environmental processes contributing to its discontinuous distribution.

Keywords: *Harpadon nehereus,* Distribution, Remote sensing

FM/O-4

Biophysical drivers of *Sardinella aurita* in Ivorian waters: Applications from remote-sensing observations and GIS

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The coastal regions of the Gulf of Guinea constitute one of the major marine ecosystems producing essential living marine resources for the populations of Western Africa. In this region, the Ivorian continental shelf has been subject to strong anthropogenic pressures associated with increased population size, economic development, urbanisation, pollution discharge, habitat degradation, unsustainable fishing practices and climate change. Cumulatively, these changes have put the regional fish stocks, especially *Sardinella aurita,* under threat of overfishing. In this context, an assessment of the risks and vulnerabilities of the marine environment is essential for responsible management of fishery resources. Here, we combine *in-situ* observations of *Sardinella aurita,* catch from the Ministry of Fisheries in Abidjan (Ivory Coast), with high-resolution remote-sensing ocean-colour data from the European Space Agency Climate Change Initiative ESA OC-CCI project (comprising merged, bias-corrected data from MERIS, MODIS and SeaWiFS), and wind and Sea Surface Temperature (SST) data from the European Centre for Medium-Range Weather Forecast. We establish quantitative relationships between *Sardinella aurita* catch and oceanic primary producers (including phytoplankton phenology, and phytoplankton biomass as the primary source of food for the fish larvae), and between *Sardinella aurita* catch and the environmental conditions (*i.e.*, upwelling index and turbulence). These relationships are used to construct diagnostic models, providing powerful tool to support evaluation and monitoring of fishing activity, which may help towards the development of a Fisheries Information and Management System.

Keywords: Biophysical drivers, *Sardinella aurita,* Remote-sensing, GIS

FM/O-5

Estimating bio-optical properties of Chilika lagoon for ecosystem analysis using *in-situ* and ocean color satellite data

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This study describes the optical complexity of Chilika lake, and the potential use of ocean colour data like Oceansat 2 OCM/ SUOMI-VIIRS for continuous monitoring of the bio-optical properties. First part of this study involves retrieval of remote sensing reflectance (Rrs) over Chilika lake from satellite measured top of atmosphere (TOA) radiance. Standard atmospheric correction procedure used for ocean color sensor assumes water to be black in NIR wavelengths (black pixel approximation). NIR bands are thus used for calculating aerosol path radiance over Case1 waters. Since black pixel approximation fails for turbid Case 2 waters, we used a simple technique in which we first calculated the aerosol type from waters with insignificant level of turbidity within a spatial scale of 50 km. Assuming that the type of aerosol does not change within such small spatial scale, aerosol information is used over Chilika lagoon for atmospheric correction.

In the second part of this study, we have proposed a semi-analytical (SA) algorithm to estimate chlorophyll-a concentration over Chilika lake using Rrs at three wavelengths, *i.e.*, 555nm(λ_1), 620 or 670nm(λ_2), and 740nm(λ_3). Rrs(λ) is related to the ratio of total absorption coefficient a(λ) and total backscattering coefficient bb(λ) of the water column. Assuming that total absorption coefficient at wavelength λ_3 does not depend on phytoplankton and CDOM, Rrs (λ_3) is used to retrieve backscattering property of the water column. This information is then extrapolated to the visible domain to calculate backscattering coefficient at other two wavelengths. Another important assumption which has been incorporated is that the absorption by CDOM at wavelength λ_2 is negligible. The ratio Rrs(λ_1)/Rrs(λ_2) is then expressed analytically in terms of CDOM absorption coefficient ($a_{cdom}(\lambda)$), phytoplankton specific absorption coefficient ($a_{ph}^*(\lambda)$) and chlorophyll-a concentration (C). The two unknowns of the equations, *i.e.*, $a_{cdom}(\lambda_1)$ and $a_{ph}^*(\lambda_2)$ were calculated using least square fitting technique for which *in-situ* data sets from 20 different locations of Chilika lagoon were used. The values of $a_{cdom}(\lambda_1)$ and $a_{ph}^*(\lambda_2)$ thus retrieved were 0.5786 m^{-1} and 0.0487 m^2/mg respectively with r^2 equal to 0.8498 and the value of $a_{ph}^*(\lambda_1)$ was taken from literature. The SA model was applied to Rrs(λ) measured from Oceansat-2 OCM and VIIRS to generate chlorophyll-*a* maps of the lagoon. Results are compared with *in-situ* measured values and discussed.

Keywords: Chlorophyll, Chilika, Oceansat-2OCM, VIIRS

FM/P-1

Validation of Tuna Potential Fishing Zone advisories of Lakshadweep with a note on tuna habitat preferences and biology

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Tuna is the major fishery resource of Lakshadweep Islands and with an aim to help the fishermen to locate tuna fishing grounds, the Indian National Centre for Ocean Information Services (INCOIS) based at Hyderabad developed the fishery advisories for tuna. These advisories were shared with fishermen of the island and validation was done from Minicoy, Androth, Kavarathi and Kalpeni during the period August 2015 to March 2017.

The catch composition, total number, weight and the price per kg of each resource and the total income per boat were noted from the boats which operated in the PFZ areas. The validation results indicated that there is month-wise variation in the catch form PFZ and non PFZ areas and accordingly the profit also varied. The major high value large pelagics observed in the PFZ catch were *Katsuwonus pelamis, Euthynnus affinis, Thunnus albacares, Elagattis bipinnulata, Auxis thazard, Caranx ignobilis, Istiophorus platypterus* and *Acanthocybium solandri.* It was observed that during August and October, the catch was higher by 87 and 31 % respectively in PFZ areas than non PFZ areas. The profit was nearly 90% more in August, but in October the profit was at par with non PFZ area. During November to February, the catch was higher in the non PFZ areas at Agathi, Minicoy and Andorth. Sometimes at PFZ locations dolphins, small fishes and other larger fishes which do not have good market value were more and tunas were practically absent.

Survey conducted among the fishermen indicated that at Androth, they follow the PFZ advisory but often they were able to get good catch from nearby grounds. Hence they are reluctant to travel longer distance if the predicted PFZ advisory was far from the village. The fishermen prefer the traditional methods of identifying fishing locations by following the water current, the presence of bait fishes and information provided by the other fishermen. However, several fishermen wanted to explore the viability of PFZ. The tuna advisories were useful, but there is scope to increase the accuracy of PFZ advisories. The details of catch composition and profit are presented along with the post-harvest processes, tuna habitat characteristics and biology of the tunas.

Keywords: Tuna Potential Fishing Zone, Lakshadweep tuna habitat

FM/P-2

Fishery management initiatives by dissemination of early warning alerts on ocean condition in west Africa

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The fishery resources of west Africa are over exploited and require urgent management interventions. With the contributions of climate change to the dwindling fish stocks in the sub-region, Illegal Unregulated and Unreported (IUU) fishing continues to aggravate the depletion of fishery resources in west Africa. Artisanal fishermen in the sub-region also take huge risks in going to sea without prior knowledge of ocean conditions. Their inability to obtain forecast of ocean conditions prior to embarking on fishing expeditions expose them to the perils of the boisterous sea. In order to support the fight against IUU in west Africa and also to provide reliable early warning ocean condition information to fishermen prior to their fishing expeditions, the project on Monitoring for Environment and Security in Africa (MESA) was initiated. The ECOWAS Marine Thema of the MESA Project provides information on potential fishing zones (PFZs) using Earth Observation data. The Project, which was executed by the University of Ghana was sponsored by the European Union under the tenth European Development Funds (EDF) and comprised 14 coastal west African beneficiary countries. This information is used by fisheries managers for monitoring and managing the fishery resources. Additionally, forecasts of ocean condition parameters are generated and disseminated to local fishermen via an SMS early warning system.

Keywords: IUU fishing, MESA, Ocean conditions early warning, Potential Fishing Zones, west Africa

FM/P-3

Geospatial variation and forecast modelling of *Thunnus albacares* along Indian coast: Remote sensing approach

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Yellowfin tuna (*Thunnus albacares*) is a highly migratory species, widely distributed over very vast oceanic extent and forms large schools. The cosmopolitan distribution of yellowfin tuna cause longer scouting time which leads to excessive fuel consumption to fishers. Hence, predicting fishable aggregations of the species makes fishing more efficient and economically feasible. To achieve this, it would be useful to analyse long–term fisheries and oceanographic data that could affect the geospatial distribution of yellowfin tuna. This study aims to illustrate how remotely sensed oceanic variables and hook and line catch data can be used to forecast presence and geospatial distribution of yellowfin tuna (*Thunnus albacares*) along the Indian coast. Hook and line catch data of yellowfin tuna from Fishery Survey of India (FSI) vessels operated from Mumbai, Goa, Chennai and Port Blair having 212 records spanning all the seasons during year 2008-2012 were used. Remotely sensed oceanic variables like Sea Surface Temperature (SST) (L4 gridded products) are generated by combining complementary satellite and *in-situ* observations within Optimal Interpolation systems. Sea Surface Height anomaly (SSHa) relative to the geoid obtained from AVISO (Archiving, Validation and Interpretation of Satellite Oceanographic) observations with multiple altimeter satellites were also generated. Multiple Regression equation with number of individual fish hooked as dependant variable (Y) and SSHa (X_1) and SST (X_2) as independent variables were built to forecast presence of yellowfin tuna along Indian coast. Average hooking rate was high (1.0067) along northwest coast followed by southeast (0.6563). The multiple regression equation obtained were $Y= 2.86+0.174(X_1)-0.000023(X_2)$ with coefficient of determination (R^2) 0.049 indicating variation due to independent variables. SSHa showed positive correlation with yellowfin tuna catch except southwest and Andaman and Nicobar coast.

Keywords: Remote sensing, Yellowfin tuna, Sea Surface Temperature, Sea Surface Height anomaly

FM/P-4

The effect of increase of temperature on primary productivity in relation to the decrease of fisheries in the western Indian Ocean

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The western Indian Ocean has been experiencing one of the largest warming trends over the tropical oceans where its surface waters are warming by 0.04ºC per decade. It contains the largest concentration of phytoplankton blooms during the summer and hence support the most economically valuable tuna fishery. The region has shown the largest warming trend in sea surface temperatures in the tropics during the past century. There has been a decrease of upto 20% in phytoplankton biomass in this region over the past six decades and a decline of 30% in phytoplankton biomass during the past 16 years as a result of increase in temperature. The trends in decrease of chlorophyll concentration has been contributed by ocean stratification due to rapid warming in the Indian Ocean, which suppresses nutrient mixing from subsurface layers.

The rising of Sea Surface Temperature (SST) has been influencing the near-surface stratification which inhibit the vertical mixing process essential for introducing nutrients into the euphotic zone where there is availability of sufficient light for photosynthesis. The trend analyses of nitrate, phosphate, and silicate concentrations indicated that the nutrient concentrations have reduced in the western Indian Ocean and around the southern tip of Indian peninsula, where the chlorophyll concentrations also shown a decrease.

It is very well recognized that distribution and abundance of pelagic fish species such as tuna is associated with the phytoplankton availability and hence changes in plankton production have immense impact on the marine species. Increase in stratification and reduced mixing of water reducing primary productivity and ultimately food supplies for fish species in turn lead to reduction in fish stocks and fisheries.

In the present study we used chlorophyll and SST data from the European Space Agency to analyze the effects of temperature on trends of chlorophyll while the fish catch data were obtained from the Food and Agriculture Organization (FAO) of the United Nations. We also investigated the effect of increase of temperature on primary productivity in relation to the decrease of fisheries in the western Indian Ocean.

Keywords: Chlorophyll, SST, Fisheries, Nutrients, Stratification, Western Indian Ocean

FM/P-5

Does the Indian Ocean Dipole (IOD) regulate the annual oil sardine (*Sardinella longiceps)* landings in Kerala?

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The *Sardinella longiceps* is the major pelagic fish landed in Kerala along the south west coast of India and an important income and resource for the local coastal villages. The fluctuations in the annual landings of sardines are influenced by several physical forcing mechanisms in the ocean such as the seasonally reversing monsoon winds, Sea Surface Temperature (SST), monsoon rainfall and Sea Level Anomaly (SLA). In addition to these local physical forcing mechanisms, the circulation in the eastern Arabian Sea off the Kerala coast is also influenced by the Indian Ocean Dipole (IOD), characterized by basin-scale SST and wind anomalies. The positive phase of IOD (PIOD) results in anomalous increase of SSTs in the western tropical Indian Ocean and anomalous cooling in the eastern tropical Indian Ocean. In contrast, during the negative phase of IOD (NIOD), the western Indian Ocean is characterized by cooler than normal SSTs and anomalously warm SSTs are present in the eastern tropical Indian Ocean. The intensity of IOD is measured as the difference in SST anomalies between a region in the western equatorial Indian Ocean (50°E-70°E, 10°S-10°N) and a box in the eastern equatorial Indian ocean (90°E-110°E, 10°S-0°N) the Dipole Mode Index (DMI). In the present study an attempt has been made to analyse the fluctuations of IOD in combination with the annual sardine landings in Kerala during the 19-year period (1998-2016). The linear correlation coefficient between the annual DMI index and sardine landings off the Kerala coast is found to be 0.73, statistically significant at the 99% confidence level. This means that IOD is able to explain about 50% (COD = 0.53) of the annual sardine variability in Kerala. The influence of IOD on the biology of sardine is analysed in detail to elucidate a relation to explain the fluctuation in sardine fishery.

Keywords: Arabian Sea, Oil sardine, Indian Ocean Dipole, SST, DMI

FM/P-6

A study on coastal eddy association with mud bank during southwest monsoon along Kerala coast, India

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The oceanic and atmospheric properties synergistically influence the primary productivity, which has a major role on species distribution, community composition, phenology and abundance within the localized ecosystem based on the interaction of species at various trophic levels. Coastal eddies are rotating water masses broken off from a strong coastal front and can pump sub-surface nutrient rich water to the euphotic zone. The effect of falling sea surface height can be observed in the cold core eddies. These cold core eddies enhance supply of sub-surface nutrient-rich water to the euphotic zone, where primary production takes place in the presence of sunlight. The occurrence of cold core eddies create a different physico-chemical dynamic in the oceanic ecosystem, which enhances chlorophyll-*a* biomass near the surface water in the core region of eddies. The sea surface slope in certain areas may result in changes in temperature, salinity and currents. Mud banks are calm water patches along the coastline with high suspended particles which facilitate damping of waves, makes the ocean surface calm and conducive for fishing activities. Exceptionally biologically productive mud banks along Kerala is unique in their formation and functions, as they appear only during peak southwest monsoon. Intense fall in sea surface height has been observed at Malappuram during second of June, 2013 and the intensity of the fall further increased in third week of July with the extension towards mud bank ground at Thrissur and Alappuzha. But, a comprehensive study on the role of coastal eddy and sea level anomaly is required, which we elucidate in the present study, as deciphered from satellite remote sensing data in supports of mud banks and its fishery in the coastal water of Kerala.

Keywords: Eddy, Fishery, Mud bank, Sea Surface Height

FM/P-7

Designs, operational aspects and GIS mapping of dolnets of Maharashtra, India

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Dol nets are traditional fixed bag nets operated in areas of strong tidal currents along northwest coast of India targeting mainly Bombay duck and non-penaeid prawns. As per the 2010, Marine census conducted by CMFRI, Maharashtra state has the maximum number of dol nets and is mainly operated along Palghar, Thane, Greater Mumbai, Raigad and Ratnagiri districts. Dolnetters accounted for about 25% of the total fishery and thus it supports the livelihood of a major population of fishermen in Maharashtra. A study was conducted to document operational aspects, catch composition and designs of dolnets of Maharashtra and to map them in GIS platform. Operation as well as designs of dolnets varies with geography, area of operation, seasons, species targeted etc. Mechanization of traditional crafts in Maharashtra help the fishers to operate dolnets upto depths of 40-50 m compared to operation maximum of 20–25m depth with the help of traditional crafts. Specially modified dolnets called as Karli dol, Machardhanis, Ghani dol, Bokshi net, Perkawala net *etc.* have been documented in the study with their design and catch composition. The information obtained through the study is plotted in GIS platform and can offer an input for the formulation of fishery management plans and policies for conservation and management dolnet fishery.

Keywords: Catch composition, GIS, Dolnetters, Mechanization

Additional Abstracts

BD/O-6

Biodiversity of benthic fauna off Veraval coast, Gujarat-an overview

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The coastal marine benthic communities are threatened by human activities, and the present rate of habitat degradation is alarming. Benthic organisms that reside on or in sediments have to be described, as it is likely that species may get lost without ecologists knowing they existed. It is therefore important to improve our understanding of benthic biodiversity. The biodiversity of epifauna, macrofauna and meiofauna along Veraval coast of Gujarat (20°54′ 40′′ N lat and 70°22′ 12′′ E long) was studied under the project 'Investigations on the effect of bottom trawling on the benthic fauna off Saurashtra coast (Gujarat)'. Monthly sampling was done in five transects of water depths 15-20 m (D_1), 21-25 m (D_2), 26-30 m (D_3), 31-35 m (D_4) and 36-40 m (D_5) during the period September 2005 to April 2007. As many as 80 species of epifauna were recorded in the study area - 41 species of gastropods, 1 species of scaphopod, 19 species of bivalves, 3 species of crab, 3 species of shrimps, 2 species of *Balanus*, 1 species of stomatopod, 4 species of finfishes, 2 species of brown algae and 4 species of octocorals. The species diversity ranged from 1.52 to 2.14; species richness was from 1.63 to 2.91 and species evenness from 0.77 to 0.93. The maximum diversity was recorded at D5 (36-40 m) and minimum at D2 (21-25 m). The values of total taxonomic distinctness (925.11) and phylogenetic diversity (620) were also more at D5 compared to other water depths.

The groups of macrofauna represented were polychaetes, molluscs (gastropods, bivalves and scaphopods), crustaceans (crab, shrimp, cumaceans, amphipods, ostracods, isopods, copepods, squilla, balanids), foraminiferans, nemerteans, cnidaria (octocorals), sipunculids, teleost fishes (mainly *Trypauchen vagina* followed by *Filimanus similis*, leptocephalus and *Cynoglossus* sp.), pogonophores, pterobranchia and brittle stars. The species diversity ranged from 2.43 to 3.09; species richness was from 3.21 to 5.63 and species evenness from 0.69 to 0.82. The maximum diversity was recorded at D5 (36-40 m) and minimum at D4 (31-35 m). The diversity indices viz., S (species), Margalef index, Brillouin index, Fisher's alpha, Shannon index, Simpson's index and Hill's number (N_1& N_2) were noted to be highest at D5. The Abundance Biomass Curve and w-statistic of the fauna were moderately or grossly stressed.

The meiobenthos were represented by eight groups, of which the nematodes (48%) constituted the bulk of the population followed by foraminiferans (47%). Polychaetes, kinorhynchs, harpacticoid copepods, ostracods, acari, and bivalves were present in low densities and were of irregular occurrence. More than 90% of the fauna resided in the upper core. The species diversity ranged from 0.54 to 0.70; species richness was from

0.37 to 0.59 and species evenness from 0.45 to 0.72. The Abundance Biomass Curve and w-statistic indicated that the fauna were grossly stressed in the upper core at all water depths.

The variations in sedimentary organic matter and sediment texture with water depth were analysed to study the interrelationship between different measures of biodiversity and sediment characteristics. Organic matter content in shallow depths was significantly higher. The proportion of sand increased with water depth. This dissimilarity is reflected in the faunal biodiversity showing higher diversity of epifauna and macrofauna at 36-40 m water depth. The mieofaunal distribution indicated highest density at 35-40 m and peak diversity at 15-20 m.

Continuous monitoring of benthos in coastal area and cataloguing the biodiversity will aid in assessing the damage inflicted by human-induced threats like bottom trawling and pollution to biodiversity. Generation of benthic baseline data will enable to adopt coastal management strategies towards conservation of benthos.

Keywords: Habit degradation, Biodiversity, Fauna

AEE/O-11

Remote Sensing Tutorials For Capacity Building Across The Globe

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To enhance scientific and technical capacity in the fields of meteorology and oceanography within member countries, the Pan Ocean Remote Sensing Conference Association (PORSEC Ass.) has sponsored a short tutorial in association with its bi-annual conferences, held since 1992. Over the past 25 years 13 PORSECs have been held – in Australia (1994), Brazil (2016), Canada (1996), Chile (2004), China (1998, 2008), Taiwan (2010), India (2000, 2012), Indonesia (2002, 2014), Japan (1992), and in South Korea (2006). The tutorials, held with every conference since 2004, focus on existing instruments in space; and on methods of analysis and visualization. The student participants are provided practical exercises along with a variety of data and software. Using the data of polar orbiting Advanced Very High Resolution Radiometer (AVHRR), and the Moderate Resolution Imaging Spectroradiometer (MODIS) has become a staple at all the tutorials – and has found much practical use for finding ocean fronts to help fisheries, in both the developed and developing countries. Similarly, hands-on activities using passive and active microwave data from instruments such as the Special Sensor Microwave Imager (SSM/I); the Advanced Microwave Instrument (AMI) onboard METOP – for observing atmospheric moisture, clouds and precipitation; and the U.S. (SEAWINDS) and the European (onboard ERS1 and ERS2) scatterometers – for measuring surface winds over the ocean are also routinely used now. Use of altimetry for ocean topography and determination of currents; as well as the relatively less-known Synthetic Aperture Radar data from the ESA and CSA satellites have also been included. Theoretical background, instrument details, and the products from the sensors have been discussed and examples given of how the data can be used in operational settings and for research. A special feature has been a lecture by International Journal of Remote Sensing editor-in-chief Arthur Cracknell on scientific and technical writing and presentations. In summary, the students and early-career researchers are benefitting from a complete package that introduces them to the field of satellite remote sensing and analysis techniques. In this talk, we present the conference and pre-conference tutorial (PCT) framework, and associated logistics, as evolved through the time.

Keywords: PORSEC, Remote sensing, Capacity building, Tutorial

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