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Marine Mammals — Indian Scenario

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Marine mammals, the most amazing marine organisms on earth, are often referred to as "sentinels" of ocean health. These include approximately 127 species belonging to three major taxonomic orders, namely Cetacea (whales, dolphins, and porpoises), Sirenia (manatees and dugong) and Carnivora (sea otters, polar bears and pinnipeds) (Jefferson et al., 2008). These organisms are known to inhabit oceans and seas, as well as estuaries, and are distributed from the polar to the tropical regions. These organisms are the top predators in many ocean food webs except the sirenians, which are herbivores. However, cetaceans become the dominant group of marine mammals, as well as widest geographic range. Marine mammals have been deemed "invaluable components" of the naval force as their natural senses are superior to technology in rough weather and noisy areas.

India, with a rich diversity of marine mammals has a history of documenting these animals for the last 200 years. However, until the year 2003, information on these organisms in our seas was restricted to incidental capture by fishing gears and stranding records (Vivekanandan and Jeyachandran, 2012). Published reports indicate that only a few scientific studies have addressed the distribution of marine mammals in the Indian EEZ, and there exist huge lacunae on the baseline information such as abundance and density for many species due to limited resources and lack of systematic surveys. Lack of such critical information is therefore detrimental to their conservation, consequentially hampering the identification and assessment of potential threats on the wild populations, and eventually the evaluation of mitigation and conservation measures on their population.
Marine mammals are represented from two orders namely Cetacea and Sirenia in Indian waters. The Indian seas support 27 species of marine mammals including 26 species of cetaceans and one species of sirenians (dugong). The species diversity of marine mammals in India is one among the richest in the Indian Ocean (Kannan and Rajagopalan, 2013). Cetaceans diversity was highest in the Gulf of Mannar on the Southeast coast of India, which comprises 14 species and in Arabian Sea, it was 12-13 species (Kumarran, 2012). In India, all marine mammals are protected under the Wildlife (Protection) Act, 1972 (Rajagopalan and Menon 2003).

The collection of distribution and abundance data on marine mammals is generally difficult due to their highly mobile nature and low densities. Since they are mostly underwater and expose only a part of their head, or back or dorsal fin while surfacing, spotting and tracking them during field observation are challenging tasks even during good survey condition. A few dedicated as well as opportunistic surveys have been initiated to understand their spatial

Porpoising - Striped dolphin

Leaping - Spinner dolphin

Jumping - Bottlenose dolphin

Observer on "Big-eyes"or long-range binoculars distribution and abundance in India. The plausible reason for the small numbers of dedicated surveys are generally due to high operational costs and lack of know-how. To address this issue, the Centre for Marine Living Resources and Ecology (CMLRE), Ministry of Earth Sciences, Govt. of India, a premier marine research institute on Marine Living Resources is undertaking dedicated surveys for the first time in Indian waters using " big-eyes" or long range binoculars mounted on-board FORV Sagar Sampada. Fujinon 25×150 MT "Big-eye" binoculars are useful to precisely identify marine mammals at approximately 10-14 km from the observation platform. Big-eye binoculars will be used to collect critical ground-truth visual observations of mammals from the research vessel. Data from such surveys can be useful to estimate population abundance, distribution and oceanographic conditions.

The International Union for Conservation of Nature (IUCN) list for endangered species has enlisted marine mammals among the most endangered animals, many species are expected to become extinct if no conservation measures are undertaken. In order to facilitate conservation, further research is required to understand the biology and ecology of these organisms. It is also pertinent to ensure that conservation and management measures as well as mitigation actions that are already in place are effective by providing a yardstick to evaluate their effectiveness. The lacuna in the present knowledge about marine mammals could be filled by encouraging dedicated research on the cetaceans and other groups. Although India has the sixteenth longest coastline in the world, the population status of many species along its coasts and EEZ is largely unknown. Marine mammals are indicative species of ecosystem change and the existing research capabilities to be augmented to document the information in decadal (temporal) and ocean-basin (spatial) scales consistent with their natural histories.

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Marine plastic pollution: a looming menace

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Plastic has become an essential commodity for humans and finds ubiquitous use in our day to day life, from our kitchenware to office stationery. Being easily available in a variety of attractive and cheap forms, its pervasive use has led to the present times being regarded as the 'plastic age'. Cumulative production of plastic is greater than 8000 million metric tonnes, of which only 9% is recycled, 12% is incinerated and 79% is added to landfills or to the natural environment in other ways. Plastic production in 2015 was 380 million metric tons, which if left unchecked will double in the coming decades (Maphoto & Pravettoni 2018, Almroth & Eggert 2019). Annually, more than 10 million metric tons of plastic in various forms and sizes enters the oceans (Jambeck et al. 2015). Major source of marine plastic pollution is from the land based coastal pollution (within 50 km of coastline) that contributes to ~9 million tons per year (Jambeck et al. 2015). Plastic litter found in marine environment is mainly dominated by six materials: polypropylene (PP), polyethelyne (PE), polyvinylchloride (PVC), polyurethane (PUR), polyterephthalate (PET), and polystyrene (PS) together contributing 80% of the plastic production (Plastics Europe 2017).

Plastic pollution is the foremost threat faced by the oceans today. There is currently some preliminary understanding on the fate of plastics in the marine environment. Most of the plastic in the marine environment i.e. ~94% reaches the sea floor (Eunomia 2016), while 5% is retained at the beaches and remaining 1% remains floating at the surface of oceans. The great Pacific Garbage Patch (GPGP) is the largest floating patch of aggregated plastics, in which fishing gears contribute to the half of the mass. Such garbage patches pose a serious threat of entanglement, ingestion, suffocation, starvation etc. to marine fauna, including seabirds, fishes, turtles and whales (IUCN, 2018). Floating garbage also leads to the spread of invasive species, including pathogens to undisturbed parts of the ocean. Accumulation of plastic in beaches leads to decline in tourism related activities and income generation, while bringing major economic costs for its clean up (IUCN, 2018). Under the combined influence of wind, currents, UV radiations and other natural factors, plastics in the marine realm, undergo fragmentation into microplastics (i.e. particles <5mm) and nanoplastics (particles <100nm), and also leads to accumulation of toxic chemicals in seawater. Ingestion of these micro and nano-plastics as well as toxic chemicals by marine organisms is inevitable, since a great many planktonic and benthic fauna are non-selective filter feeders. Thus, the by productions of the degrading plastics not only accumulate in the ocean, but enter the oceanic food webs and eventually find their way into the human body, through consumption of seafood.

A preliminary study on microplastics in the marine benthic invertebrates from coastal waters of Kochi, Southeastern Arabian Sea identified the microplastics to be of polystyrene (Naidu et al. 2018). Another study revealed the presence of microplastics and colorants in edible green mussel (Perna viridis) along the southeast coast of India, and it was found that the size and color were the major factors affecting the bioavailability of microplastics to the mussels (Naidu 2019). Studies revealed that polyethylene and polypropylene were the most abundant forms of microplastics on beaches and in fish guts along the southeast coast of India (Karthik et al. 2018). Institutions under the Ministry of Earth Sciences have taken up further studies along these lines along Indian coasts.

FORV Sagar Sampada Campaign against Marine Plastic Pollution

The most important step towards combating major environment issues is by spreading awareness among general public. "Swachhata Hi Seva" has been a massive countrywide mobilization campaign on 'Plastic waste awareness and management', launched as a befitting tribute to the Father of the Nation on his 150th birth anniversary. As part of "Swachhata Hi Seva", the Centre for Marine Living Resources and Ecology (CMLRE), Ministry of Earth Sciences (MoES), Kochi organised a unique campaign to spread awareness on marine plastic pollution, especially to school students and coastal communities from 21st September to 2nd October, 2019. The only Fishery Oceanographic Research Vessel in the country, FORV Sagar Sampada, is the backbone of this 'Porbandar to Puthuvype' Campaign, which made stops at several ports during her voyage from Okha in Gujarat to Kochi in Kerala.

On 21st September, 2019, that coincided with 'Coastal Cleanup Day' researchers from CMLRE and scientists on board FORV Sagar Sampada began the programme by joining the Indian Coast Guard for a Beach Cleanup activity at Okha. The vessel set sail from Okha on 22nd September, 2019 and made port calls at Porbandar, Karwar and arrived at Kochi on 2nd October, 2019. At all ports, the vessel welcomed nearly 1000 students from school and college, along with members of general public and government officials. The students and other guests interacted with scientists and learnt about the research going on in the field. They were made aware of the looming threats of marine plastic pollution, and the adverse effects to the marine realm as well as to humans. Multilingual posters on combating plastic pollution were handed over to the visitors, and steel bottles were also distributed in an attempt to eradicate the use of plastic bottles for drinking water.

Snippets from the FORV Sagar Sampada Campaign against Marine Plastic Pollution

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Bioluminescence in the Sea




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Bioluminescence, is the emission of light by living organisms as flashes, glows and pulses. Light emission is the chemical oxidation reaction (referred to as chemiluminescence) between a light-producing molecule (luciferin) and an enzyme, named luciferase. Only very little heat is given off during this reaction and hence referred to as 'cold light'. More than 80% of the 700 known genera of bioluminescent organisms lives in the ocean (Shimomura, 2006). Evolutionary history indicates that bioluminescence has evolved many times from bacteria to fish and has powerful influence on the ecosystem dynamics. Bioluminescence is produced by a wide range of marine organisms; bacteria, algae, jelly fishes, crustaceans, fishes, etc. Microscopic organisms like bacteria and algae dominate bioluminescent organisms in terms of abundance, whereas higher organisms like fishes and crustaceans dominate in biomass. Bioluminescent organisms occupy a diverse range of habitats, from sea surface to sea floor, and from the poles to tropics (Haddock et al. 2010). Bioluminescence is the only source of light in the deep-sea and might be the most common form of communication in the deep-sea. The primary visual stimulus for many marine animals comes from bioluminescence rather than from sunlight and interestingly, most deep-sea organisms retain functional eyes at depths where sunlight never penetrates. The pattern, frequency, and wavelength of bioluminescent light vary with species and their habitat. The bioluminescence emission spectra extend over the entire visible light spectra (Figure 1). In fact, the bioluminescence shifts from violet and blue in the deep sea to blue-green in shallow waters to green-yellow on land. Most bioluminescence in the ocean lies in the blue spectra (λmax ~475 nm), since it travels farthest in seawater and can also activate rhodopsin in many marine organisms. The blue spectra is followed by green spectra and is often found in coastal and benthic bioluminescent species. This is possibly due to increased turbidity and light scattering, favouring transmission of low frequency light. The emission of bioluminescence by organisms vary from persistent bioluminescence by bacteria to extremely short flashes by organisms such as lantern fishes. In some organisms, light is emitted due to physical disturbance such as a moving objects (boat, ship), waves, breakwaters, turbulent wakes, etc. Bioluminescence serves a variety of functions in organisms that include both offensive and defensive, even within a single organism.

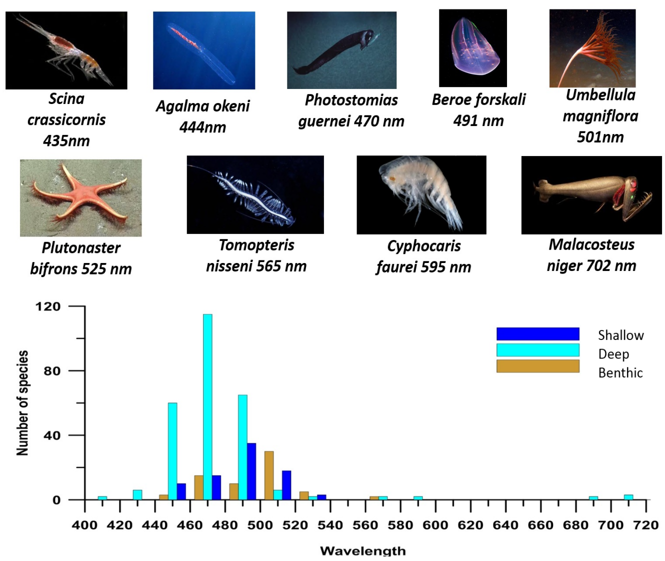


Figure 1: Bioluminescence spectra in the marine environment. The visible spectra of light in   is plotted against the number of species reported. The number of species are approximated for intervals of 20 nm. Different colour bars indicated bioluminescent organisms in different habitats (Redrawn from Widder 2010). Source of images of organisms: Wikipedia

Chemistry of Bioluminescence

Bioluminescence is generated as a result of energy released during a chemical reaction due to oxidation of a light-emitting molecule called luciferin. The emission patterns of bioluminescent organisms are remarkable ranging from continuous glow in bacteria to single flashes of light to repetitive pulse patterns in dinoflagellates (the ocean glow). The light-emitting reaction is controlled by an enzyme or photoprotein. Luciferins are highly conserved across the phyla, while luciferases and photoproteins are derived from many evolutionary lineages. It is estimated that bioluminescence has evolved more than 30 times, which suggests that the molecular building blocks of bioluminescence are ubiquitous. Nevertheless, their evolutionary origins remain mysterious. Many hypotheses suggest that bioluminescence has evolved from detoxification systems, some of the luciferins are strong antioxidants, or oxygenases with ligases as precursors of luciferases. Four luciferins are responsible for most of the bioluminescence in the ocean (Figure 2). Bacterial luminescence involves the oxidation of flavinmononucleotide ($FMNH_2$) along with a long-chain aldehyde and a two-subunit luciferase, wherein, genetic lux cassettes are responsible for light production. The dinoflagellate luciferin is a tetrapyrrole (Figure 2), similar to chlorophyll a, which can be interconverted as the cell alternates between photosynthesis and luminescence on a circadian basis (Takeuchi et al. 2005). While autotrophic dinoflagellates synthesize luciferin using chlorophyll produced by secondary or tertiary endosymbiotic plastids, heterotrophic dinoflagellates might use dietary chlorophyll for luminescence. Much of the sparkling luminescence seen in the wake of a boat at night is due to the flashing of dinoflagellates. The most common bioluminescent dinoflagellates include *Noctiluca scintillans, Protoperidinium depressum, Lingulodinium polyedrum, Pyrocystis noctiluca, Pyrocystis fusiformis, Pyrodinium bahamense,* etc. Luminescence originates in scintillons, which are microsources scattered in the cytoplasm of dinoflagellates. Mechanical disturbance in the water creates membrane deformation in the dinoflagellate cell which triggers an action potential that propagates along the vacuolar membrane. Their light emission is pH sensitive, as

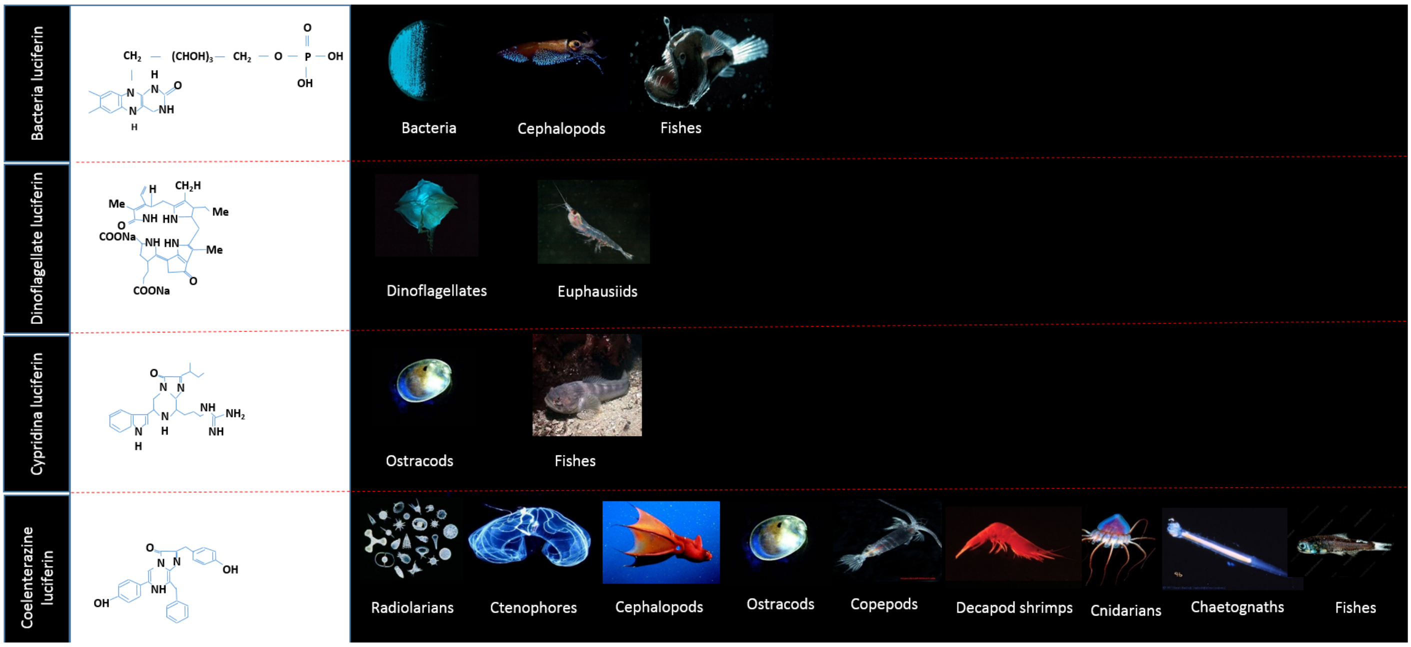


Figure 2: Four major luciferins the marine environments. The molecular structure of the luciferin and the common taxa possessing different luciferins are listed. Source of images: Wikipedia. This figure is adapted and redrawn from Widder, 2010 and Haddock et al., 2010.

luciferin is bound by a pH-sensitive luciferin-binding protein. This change in H^+ ion concentration causes the luciferase to change conformation, thereby exposing its active site to the luciferin. The flash light intensities vary among different species of dinoflagellates. It ranges from 10^9 ps^{-1} per cell for L. polyedrum to 10^{11} ps^{-1} per cell for *N. scintillans*. The duration of flashes range from 80 ms for *N. scintillans* to 130-150 ms for L. polyedrum to 500 ms for *P. fusiformis*. The number of flashes by a single cell in response to a single mechanical stimuli varies between species and stimulus history (Widder, 2010). The structure of dinoflagellate and euphausiid luciferin is similar indicating dietary linkages (Shimomura, 1995). Euphausiids produce intense bioluminescence in response to mechanical stimuli with peak photon flux of 10^{12} ps^{-1} per cell.

In the case of ostracods, *Cypridina*, luciferin is the light -emitting molecule, whereas in coelenterazine is present in cnidarians, squids and shrimps. Ostracods synthesize their luciferin from amino acids such as tryptophan, isoleucine, and arginine. Most of the ostracods have luminescent glands that release light-producing chemicals into the water. For eg., Carribean ostracod Vargula, release large diffuse clouds of luminescence that glows for many seconds to startle predators. In ostracod species, Conchoecia, bioluminescence may either be excreted or retained within the glands. Conchoecia elegans produces rapid repetitive flashes at approximately 7 flashes per second in trains of from 2 to 120 flashes per display in response to mechanical stimuli. Coelenterazine or imidazopyrazinones (a combination of 5- and 6-membered nitrogen-containing rings) is the best characterized and is found in the bioluminescent systems of at least nine different marine phyla. Coelenterazine occurs naturally in conjunction with both photoproteins and luciferases (Takenaka et al. 2008). Interestingly, chemically identical luciferin such as coelenterazine is present in unrelated organisms, spanning nine different phyla, not because of the synthesis of the same molecule, but is acquired exogenously through diet (Haddock et al., 2010).

Functions of bioluminescence

Bioluminescence is exhibited by a broad range of marine organisms with the exception of higher invertebrates. In fact, 60-80% of deep sea fish were thought to be bioluminescent. Bioluminescence serve many diverse functions in the ocean illustrated by remarkable morphological specializations ranging from luminescent structures to bioluminescent systems (Davis et al., 2014). Many of the functions still remain unknown, though some experimental evidences are available for a few. Bioluminescence is an extremely effective for invertebrates to communicate with organisms located far away. A bioluminescent flash even by a dinoflagellate cell can be identified by large fish moving 5 m away (Turner et al., 2009). Luminescence can serve various purposes attracting mates, prey, camouflage, deter predators, aposematism (warning colouration), prey luring and courtship. In general, bioluminescence is primarily used for the purpose of defense, offense and intraspecific communication (Figure 3). Bioluminescence emitted as flash, or sparks, or exudates, at close ranges can startle the predators. This is seen in many animals such as dinoflagellates, shrimps, copepods, squids and myctophids. Certain large organisms shed their luminescent parts as a sacrificial tag, which continue to glow outside the body to distract a predator as a 'Trojon horse". Counterillumination is another strategy shown by crustaceans, cephalopods and fishes, where the photophores on the ventral side match with the dim light coming from the surface, obscuring their shadow. This is achieved either through a uniform matching to the light field or by disrupting the silhouette. Deep and shallow squids and fish, *Porichthys notatus*, have shown to match the intensity and colour of downwelling light. In some organisms, bioluminescence works as burglar alarm, whereby its predators are vulnerable to attack from secondary predators. However, certain organisms use bioluminescence to attract or lure its prey. Most common example is the angler fish, which use bacteria to produce a long glow by altering the light organ, where bacteria are stored. Chiroteuthis, a squid uses its special light organs at the end of long tentacles as lures, whereas Stauroteuthis octopus uses it luminous suckers to attract its prey. Siphonophores can adopt visual mimicry

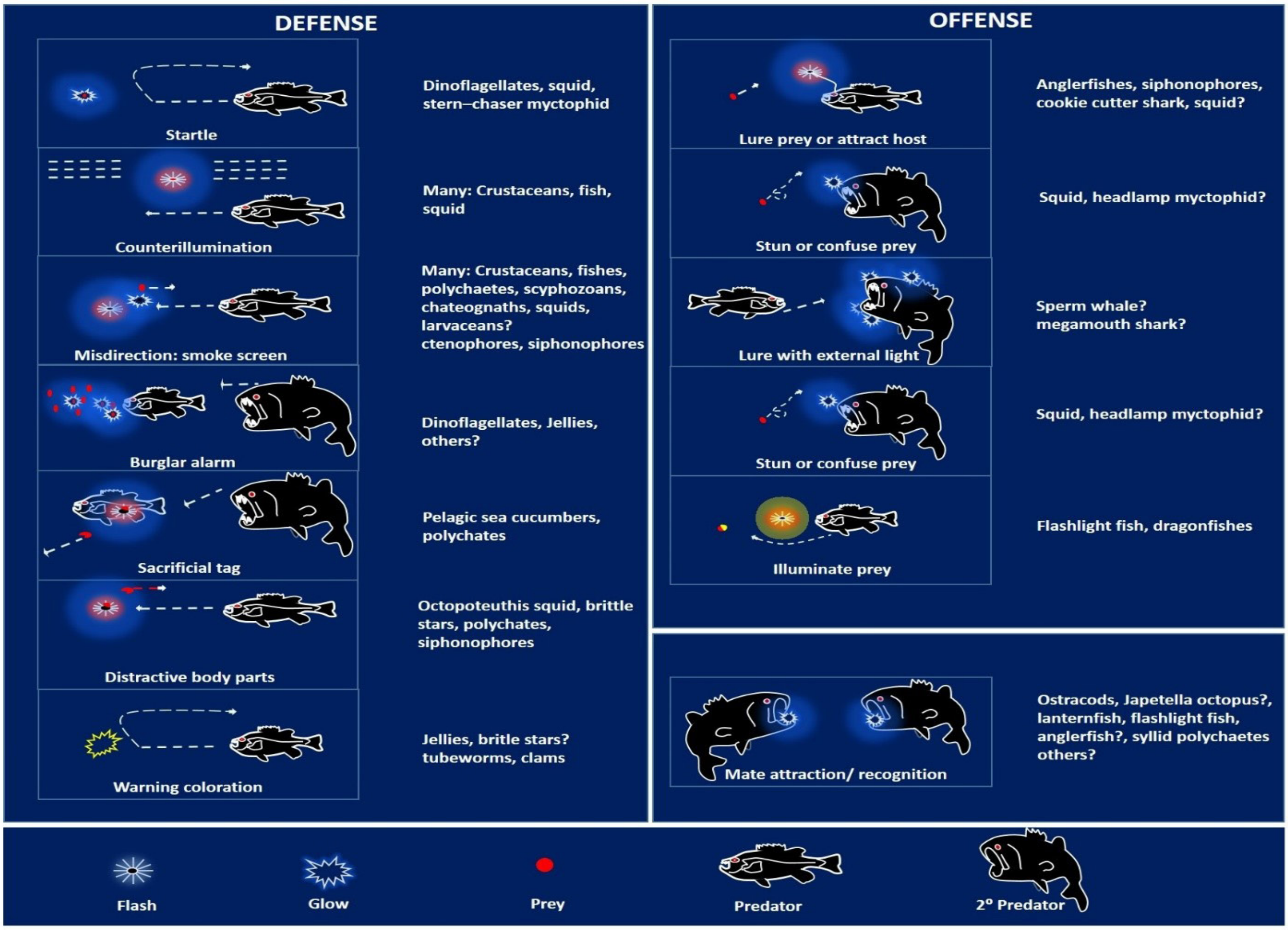


Figure 3: Schematic diagram showing the functions of marine bioluminescence, such as defense, offense and intraspecific communication. Certain organisms use bioluminescence for multiple roles (Redrawn from Haddock, 2010).

to attract prey, whereas Erenna modifies its tentacles with bioluminescent lures confuse the prey. In some species, the red fluorescent coating is seen on the bioluminescent lure to prey on fishes with long-wavelength sensitivity. The bright luminescence of myctophid fishes can also stun or confuse the prey.

Bioluminescent bacteria, such as *Aliivibrio fisherii*, is a symbiont in the light organs of Hawaiian bobtail squid, Euprymnia scolopes. Some of the incidental byproduct of metabolic functions, may also yield bioluminescence. In addition to these offense and defense functions, bioluminescence is used for intraspecific communication. Caribbean ostracods shows species-specific patterns of signalling, complex three-dimensional mate-following behaviour. Octopods Japetella and Eledonella and the ponyfishes display synchronized luminescent -based sexual dimorphism. The angler fish uses luminescent lures to find mates and to attract prey (Herring, 2007). In Japetella and firefly squid, Watasenia, bioluminescence is used to distinguish each other and to communicate, rather than for interspecific predator-prey functions.

Measurement of bioluminescence

Several instruments are used to measure the bioluminescence in the ocean (Figure 4). In mid 1950s, photomultiplier tubes were used to measure the light. Later, it was realised that light meters can stimulate bioluminescence in water. Bathyphotometers were developed to minimize stimulation during operation, which included a light detector (a photomultiplier tube) and a viewing chamber. In this, phytoplankton is disturbed mechanically to emit bioluminescence through a turbulence-generating mechanism. The photon flux generated is dependent on (1) the detection chamber volume, (2) flow rate through the chamber, (3) the intensity of stimulation and (4) the intensity of pre-stimulation. The photon flux recorded in a bathyphotometer is a function of the total photons per flash and volumetric flow through the chamber. However,

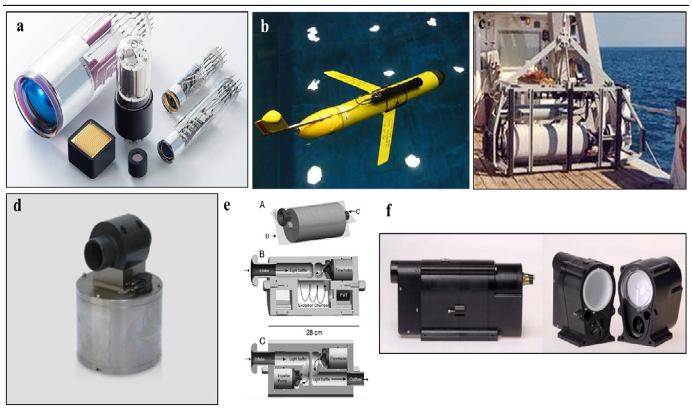


Figure 4: Field instruments used for the measurement of bioluminescence in the sea a) Photomultiplier Tube (PMT) b) AUV with Bathyphotometer c) Glowtracka d) Multipurpose Bioluminescence Bathyphotometer (MBBP) e) Underwater Bioluminescence Assessment Tool (UBAT)

the sampling efficiency was poor and biased towards weak swimmers such as dinoflagellates and lack a suitable calibrated method of stimulation making the results non-comparable. Later, the bathyphotometer was modified to develop High Intake Defined Excitation Bathyphotometer (HIDEX-BP). The instruments had high flow rates (44l/s) with a calibrated stimulus regime and long-residence-time detection chamber. HIDEX is routinely used in oceanographic research in conjunction with standard oceanographic measurements such as temperature, conductivity, turbidity, depth and fluorescence. The use of bathyphotometers has revolutionised our understanding of bioluminescence in the sea. The measurements were focused on the upper 100 m of the water column and has demonstrated that this property is ubiquitous in marine environments. However, measurement of bioluminescence should be concurrent with sampling with nets and pumps to determine the organisms responsible for producing light. A Spatial Plankton Analysis Technique (SPLAT) was later developed which uses a transect screen to mechanically stimulate bioluminescence in the plane of focus of an intensified video camera to identify and map bioluminescent organisms based on stimulated bioluminescent displays. The video recordings of the stimulated displays are analysed using an image recognition program and then reconstructs them in three-dimensional spaces and carries our statistical analysis of their spatial point patterns. This devise could capture small signatures even from dinoflagellates (of 50 mm size) in a one meter field, making this a high-frequency (30 fps) and high-resolution sampling protocol.

Recently, Plymouth Marine Laboratory developed a luminescent sensor, GLOWtracka, which records visible emissions from bioluminescent organisms. GLOWtracka, is marketed by Chelsea Technologies, and is designed to be moored, submerged, profiled with pumped systems, or deployed in towed vehicles. It has a compact design and is rugged for ease of integration with wider systems with a photodiode detector, flow meter and a data logging unit (Figure 4). Of late, a third generation multipurpose bioluminescence bathyphotometer (MBBP) was developed at the University of California, Santa Barbara as a part of the Small-business Technology Transfer program sponsored by the Office of Naval Research of USA, called the Underwater Bioluminescence Assessment Tool (U-BAT) (commercialized by WET labs). It is a small, lightweight and cost-effective bioluminescence sensor for both coastal and open ocean environments, which provide measurement of mechanically stimulated bioluminescence potential in units of photons l^{-1} and consists of a photomultiplier tube, detection chamber, and flow meter. This sensor is designed for deployment on multiple platforms such as ships, Autonomous Underwater Vehicles (AUVs) or long-term deployment moorings or buoys. UBAT provides a scalable, reliable and accurate measure of bioluminescence potential and has a resolution of 1 m vertically.

Application of bioluminescence in research

Bioluminescence has many significant applications in the marine environment and is extensively used by the mankind. Aliivibrio fischeri is used to monitor water toxicity as exposure to pollutants decreases light output in luminescent bacteria. Bioluminescent assays are extensively used to determine the amount of ATP present in cell and tissue extracts to study the energy conservation mechanisms in cells. The tribal community have used flowing fungi to illuminate their way through dense jungles. Bioluminescence could be considered as a potential form of green energy and could be envisaged to replace the street lamps by glowing trees and buildings. Bioluminescence is also used to track submarines during warfare by tracing the bioluminescent wakes produced by allies. It is said that the Photorhabdus luminescens, produce antimicrobial compounds which were directly applied on wounds of soldiers to prevent infection during American Civil War. The property of bioluminescence is well accepted as a non-acoustic method of detection of moving boats and submarines by the Navy across the world. The turbulent wake of a moving submarine mechanically stimulate bioluminescent organisms to emit light. The emitted light could be detected from above the ocean surface from a surveillance aircraft. However, the use of this method requires considerable amount of research to understand the distribution of bioluminescent organisms, rate of attenuation of bioluminescence as it travels through the water column, speed of the submarine, scattering and bioluminescence potential of organisms. Furthermore, there appears to be very little knowledge at this time regarding the geographic, seasonal and depth-wise distributions of such organisms. Another major limitation of this non-acoustic methods is overpowering background noise by both sun and moon, which may render the use of this detection system only in night conditions.

Bioluminescence has revolutionized the medical research, and is extensively used for bioluminescence imaging. Luciferase systems are used as reporter genes, such as in transgenic tobacco plants. Interestingly, it is used in cancer treatment for bioluminescent-activated destruction of cancer cells. Bioluminescent photoproteins are extensively used in biomedical research for measurement of Ca^{2+} ions as labels in binding assays and in vivo imaging of cellular processes. In 2008, the Nobel Prize in Chemistry was awarded jointly to Osamu Shimomura, Martin Chalfie and Roger Y Tsien, for the discovery and development of green fluorescent protein (GFP) which is fluorescence rather than bioluminescence. The green fluorescent protein from the crystal jellyfish, Aequorea victoria, needs to be excited by blue light before emitting its green light. Bioluminescence is also engineered for use as street lights. Researchers are trying to develop genetically engineering bioluminescent E.coli bacterial cells for use in light bulbs.

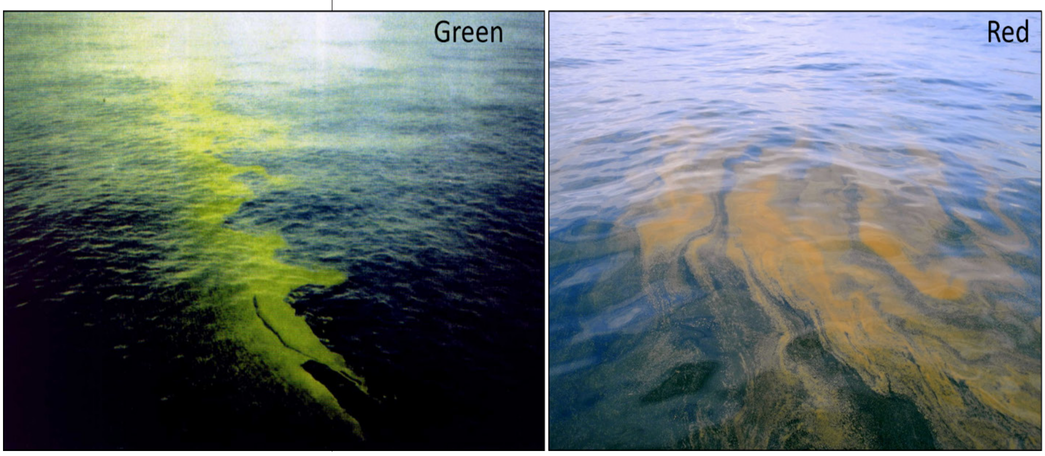
Ecology of bioluminescence in Indian waters

Dinoflagellates are one of the major eukaryotic protists capable of producing light in the marine ecosystems. They occur primarily in the surface layers and many of them are photosynthetic. During the formation of algal blooms (red- tides), the bioluminescent dinoflagellate species exhibit sparkling luminescence during night over a vast area. *Noctiluca scintillans* is one such bioluminescent dinoflagellate widely distributed in the Arabian Sea (Figure 5). There are two major strains of *Noctiluca* spp. in Indian waters, i.e., red (heterotrophic) and green (mixotrophic). Green *Noctiluca* possess a photosynthetic endosymbiont known as *Pedinomaonas noctilucae* (Green algae, class Prasinophyceae) which exhibits a phagotrophic mode of nutrition. Recent studies have shown that northern Arabian Sea favours spectacular growth of green Noctiluca blooms during the winter monsoon period. Conversely, the massive outbreaks of red *Noctiluca*, a voracious grazer, are associated with coastal upwelling in the southeastern

Figure 5. Image of *Noctiluca scintillans* (Light microscopic view)

Arabian Sea. In addition, sporadic occurrence of *Noctiluca* blooms (both green and red) were frequently reported from the east (Gulf of Mannar, Rushikulya River, Kalpakkam) and west (Trivandrum, Cochin, Calicut, Mangalore, Goa) coasts of India, irrespective of seasons. Apart from *Noctiluca*, dinoflagellate species belonging to the genus *Protoperidinium, Ceratium, Gonyaulax, Pyrophacus, Alexandrium* etc. are also found to exhibit bioluminescence property. However, their distribution in terms of abundance is relatively less in Indian waters as compared to *Noctiluca* spp. Dinoflagellates generally exhibit low flash intensity compared to zooplankton community. Since the bioluminescent dinoflagellates are uniformly distributed over a large region in high abundance, their bioluminescent flashes are more intense than the bioluminescent zooplankton species.

Among the zooplankton community, ostracods, copepods, euphausiids, cnidarians, cephalopods, chaetognaths, decapod shrimps, tunicates, etc. exhibit bioluminescence property. It has been shown that approximately 50% of bioluminescence in the northern Indian Ocean (Arabian Sea) was contributed by zooplankton such as euphausiids, copepods (*Pleuromamma* sp.), ostracods, nectophores etc. (Lapota et al. 1988). Studies have also shown that swarms of ostracods can produce continuous luminescence in the east and west coasts of India. Recently, Lakshadweep waters (Kavaratti lagoon) exhibited bioluminescence property in association with swarming of ostracods (*Cypridina hilgendorfii*). Apart from ostracods, some of the copepod species (e.g., *Pleuromamma* spp, *Metridia* spp, *Gaussia* spp. and *Oncaea* spp) also exhibit bioluminescence in the marine waters. Pleuromamma spp, (*P. indica, P gracilis, P. xipias, P.quadrungulata, P. abdominalis*) also found to exhibit bioluminescence property in the Indian Ocean (Lapota et al. 1988). In addition to copepods and ostracods, there are other organisms such as decapod shrimps (*Acanthephyra* spp and *Ophlophorus* spp), cnidarians (*Atolla* spp, *Periphylla periphylla*, *Pelagica noctiluca*), and tunicates (*Paradoliopsis* spp, *Pyrosoma* spp, *Oikopleura* spp.) that exhibit bioluminescence in the Indian waters.



Blooms of *Noctiluca scintillans* in the Arabian Sea (Green and red)

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Otoliths- Black boxes in the fishes

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Otoliths are a cellular calcium carbonate (CaCO3) structures seen in the inner ear of all teleost fishes that grow throughout the fish lifetime. The calcium carbonate is seen in the form of argonite which is very common in the corals and skeleton of sclerosponges. These structures are composed of nearly 90% of inorganic (mineral) and 10% organic (protein) materials. Otoliths are present in the vestibular labyrinth of all vertebrates including fishes (except jawless vertebrates). The sensory epithelia present in the labyrinth is divided in to three sacs like structures known as utricular, saccular and legenar maculae and each of these possess a pair of calcified structures called otoliths. The otoliths present in each of these maculae are known as asteriscus, sagitta and lapillus, respectively. These three pairs of otoliths situated in both side of the fish's cerebral hemisphere. Sagitta is the largest among the three pairs which is quite well known for their high inter-species variation in the morphology and are widely used for differentiation of fish species/stocks/populations (Fig 1). The term "otolith" used in various publications are mostly sagittal otoliths. These otoliths serve as inner ear for sound reception and a balancing organ in fishes (Lombarte and Cruz., 2007). Fishes cannot detect sound via tympanum similar to other species such as tetrapods which was compensated with otoliths. Sensory cells possess by the sensory area of the otoliths (sulcus acusticus) detect the movement of these calcareous structures in sound field while moving leads to the hearing in fishes. Studies indicated that size and shape of otoliths found to be closely related with the ecology of the species. The ratio between the area of the sulcus acusticus and area of the otolith (S:O) gives insights to the depth preferences in fishes. Previous studies indicated that S:O ratio tends to increase with increasing depth and hence, deep-sea fishes found to have relatively high S:O ratio compared to pelagic fishes (Lombarte, 1992). Deep-sea habitat is considered as a light deprived environment and the loss of vision in the area is being compensated by the development of mechanoreceptor and chemoreceptor sensorial systems and those fishes depend more on sounds for their communications.

The incorporation of mineral component in the otolith is regulated by physical and chemical properties of surrounding environment such as temperature, salinity and depth. Scientists working on otolith chemistry used these otolith characteristics to reconstruct the past environmental conditions. The elemental composition of otoliths is used as natural markers to differentiate the fish stocks/populations (Compana, 2005a). The otoliths are metabolically inert as the deposited mineral material neither resorbed nor reworked. Hence, the trace element deposited in otoliths reflects prevailing physical and chemical characteristics of the environment (Izzo et al., 2018). The isotopic ratios of

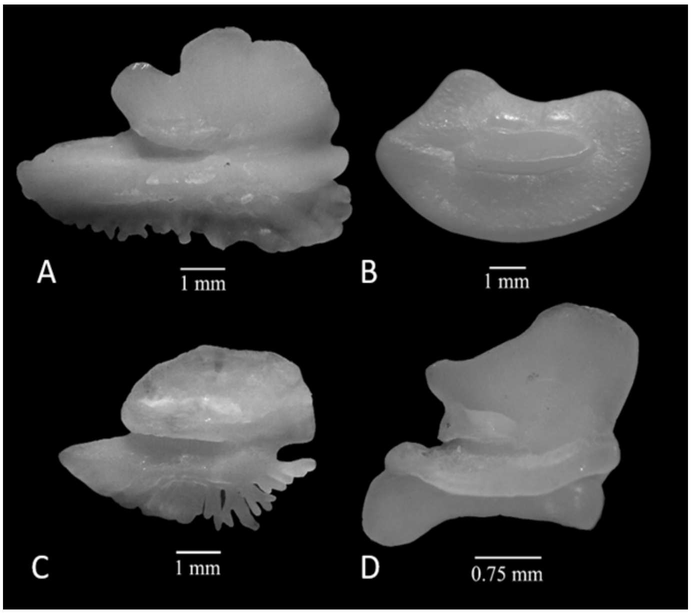

Fig 1. Otoliths of fishes collected from > 900m depth (A) A. blanfordii (TL=46cm, OL=5.365mm), (B) B. vicinus (TL=80.5cm, OL=7.69mm), (C) N. erimelas (TL=63cm, OL=5.718mm), (D) R. guentheri (TL=22cm, OL=4.17mm) (TL, total length, OL, otolith length).

oxygen, barium and strontium have been extensively used to differentiate the stocks/population and also reconstruct the past environmental conditions since these elements are influenced by the environmental conditions and availability. Hence, these isotopic ratios are known as elemental fingerprints as they make permanent impressions in the otolith.

Accurate estimation of age is an integral part of fisheries science for the management of resources and is very critical to estimate the growth, mortality rate and age structure of the population. Recently scientists depend more on otoliths for the estimation of fish age than the conventional methods based on length frequency data. The age determination in fishes using otoliths can be carried out at two different levels viz., macrostructural (annual bands) and microstructural levels (daily rings) (Compana, 2005b). The selection of the method is highly species specific since fishes show high variability in growth rate, otolith size and otolith shape, but the precision of age estimation is greatly depending upon sample preparation, the experience and accuracy of the age reader.

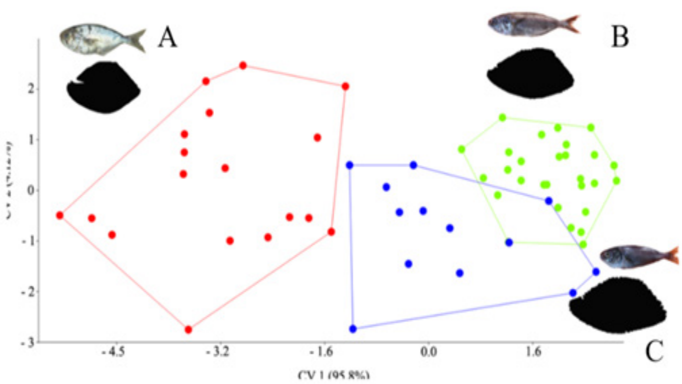

Fig. 2. Differentiation of three Psenopsis species based on otolith morphology (A, P. obscura; B, P. cyanea; C, P. intermedia).

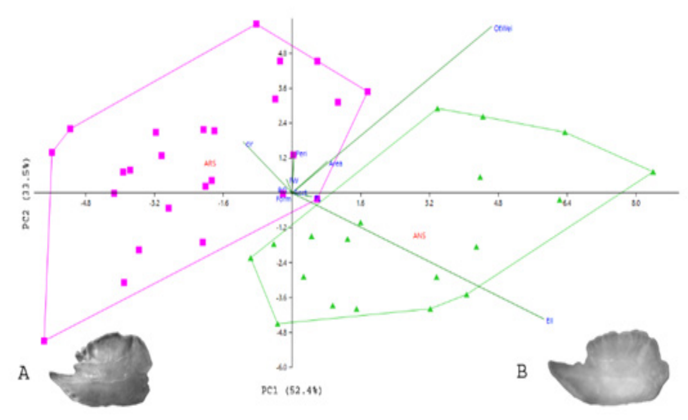

Fig. 3. Differentiation of Bembrops caudimacula based on otolith morphometric measurements.

The high inter-species variability in the otolith morphology is used by the researchers to differentiate the species/stocks/populations accurately (Fig 2, 3). After the advancement of image analyzing systems with the support of various statistical analyses such as wavelet and Fourier, scientists are able to differentiate the species based on otolith shape accurately. During the last decade, number of studies have come out on these aspects and found the method is effective. Reconstructing the past species assemblages using otoliths collected from sediments is a recent advance in the otolith research (Lin et al., 2019).

Otoliths are very useful in the food and feeding studies of fishes, especially for deep-sea fishes. Since the gut in the deep-sea fish either remains as empty or with completely digested matter, precise identification of the prey type is extremely difficult in these conditions. Otoliths will remain in the gut of these species along with other hard parts such as scales and fish bones, without significant damage. Scales and bones provide unrealistic estimates on the prey type and size. Due to the large size and high inter-species variability, sagittal otoliths are very helpful to identify the prey type and size for the food and feeding as well as food web dynamics studies. The numerical models derived from simple linear regressions on various otolith morphometric measurements are used to back calculate the prey size (Kumar et al., 2017). The various otolith atlases published are helpful for identifying the species at least up to genus level.

In this regard, CMLRE has initiated research in 2014, on the differentiation of fish stocks using otolith morphology and morphometry and have published promising results in various peer-reviewed journals. This technique is now well accepted as a easy and inexpensive method to differentiate the stocks compared to the molecular analysis which is expensive and time-consuming. Recently CMLRE has successfully differentiated the population of a deep-sea fish Bembrops caudimacula (Opal fish), a very common species seen in both Arabian Sea and Bay of Bengal (200-400m) using otolith morphometric analysis (Deepa et al., 2019). Models developed by the scientists at CMLRE using various otolith morphometric measurements are very useful for estimating the prey size for food and feeding, and paleontological studies. Otoliths are nowadays very popular among fish biologists as a tool for understanding various ecological characteristics of fishes such as hearing efficiency, habitat preference and locomotion capacities etc. Further, we have initiated studies on depth related changes in the sound reception capacities of fishes using otoliths. Results suggested that there is an increase in the sound reception capacities of fishes with depths up to 900 m and declines thereafter. CMLRE has initiated the setting up of India's first otolith museum for the deep-sea fishes of India along with digital library which would be very much beneficial for the taxonomists, ecologists and palaeontologists of our country and abroad.

Considering the application of otoliths in various fields of ichthyology viz., taxonomy, age determination, stock differentiation, reconstructing the past environmental events and species assemblages, in understanding the life history of fishes, feeding, breeding and migrations, the otoliths are well known as the "black box of teleost fish" among researchers. It records many crucial and vital information as black box (flight data recorder) does in an aircraft.

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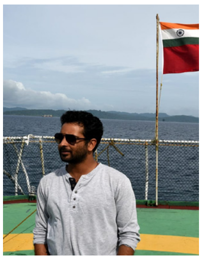
Two new species of marine flatworms from Lakshadweep Islands



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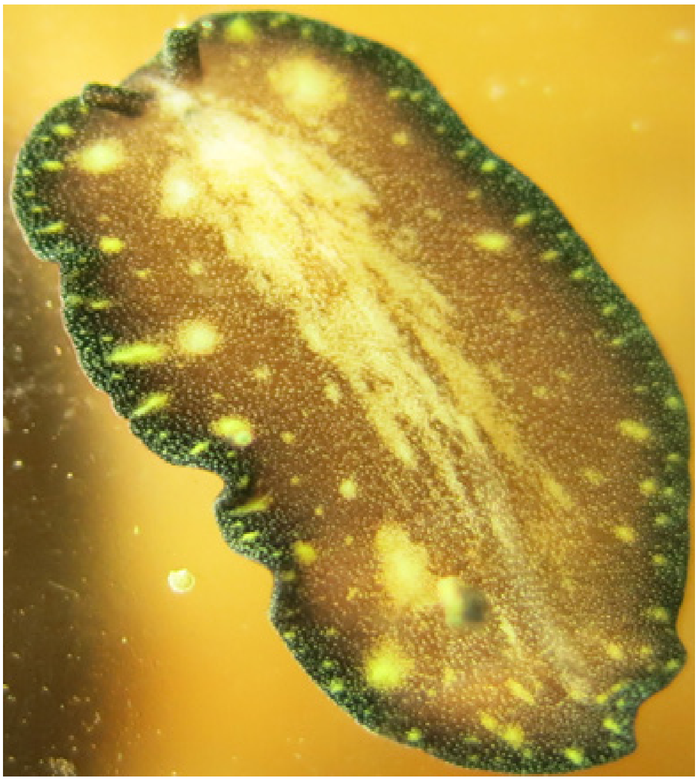
The order Polycladida under the Phylum Platyhelminthes represents a group of unsegmented, stunning and intriguing coloured free living marine flatworms, which are an ace predators with a very complex body systems despite of being primitive and one of the oldest living creatures on earth. With average size range from 10mm to 15mm, these are considered as the most primitive bilaterally symmetrical animals. These worms can be found crawling or hiding under stones from intertidal to sub tidal region, sometimes swimming over coral reefs, sandy slopes and are most active under darker conditions. Polyclads are found throughout the world, but are most colourful in tropical waters yet studies regarding these worm are very less and awaits serious attention. Polyclads are an integral part of coral reef ecosystem as they prey on variety of animals like sponges, ascidians, sea anemones etc. On some occasions polyclads are also seen preying upon crabs, molluscs and other flatworms too!

First study on Indian polyclads was done by British naturalist Laidlaw in the year 1902 when he described 7 new polyclads from Minicoy Island. Since then, till 2011 not even a single polyclad was either recorded or studied from Indian waters. A century later, in the year 2011, two papers recorded some new records of polylads from Andaman and Nicobar Islands (Sreeraj & Raghunatahn, 2011) and Kavaratti Island, Lakshadweep (Apte & Pitale, 2011) and restarted polyclad research in Indian seas. Since then regular papers are being published delaing with polylcads from Andaman and Nicobar Islands (Dixit & Raghunathan, 2013; Dixit et al. 2015) and West Coast of India (Pitale et al. 2014; Pitale and Apte, 2017). As far as new species description of polyclads from India is concerned, seven new species of Polyclads are described as new to science (Dixit at al.2017 a,b; 2018). As of now, a total of 57 species have been reported from Indian waters while around 1012 species are reported from world oceans.

Recent field studies conducted by CMLRE in Agatti Island in the years 2018-2019 revealed two species as new to science (Dixit et al. 2019). This was the first study on polyclads from Agatti Island and first description of any polyclad from these islands since 1902. The two species were named as *Pseudoceros agattiensis* and *Pseudoceros stellans*. The genus Pseudoceros under which these species are described is known for species memebers with extravagant colouration and patterns. *Pseudoceros agattiensis* is named after Agatti Island while *Pseudoceros stellans* was named for starry or star studded appearance on its dorsal side. Both the species were collected from intertidal area at eastern side during low tide.
Polyclads are one of the lesser known marine faunal groups from Indian waters. Spotting one in wild and then its collection is the tricky part. Even if a polyclad is collected, the battle is still half won until it is fixed and preserved properly for further taxonomic studies (as most flatworms tend to shrink, break or dissolve during fixing). Many species are often cryptically camouflaged and difficult to spot even in day light. The above mentioned reasons are good enough to pull off many young researchers who try to study them and these

Pseudoceros agattiensis



Pseudoceros stellans

are the reasons behind such less studied on these beautiful creatures from Indian waters. However, with advances in preservation techniques and fast developing underwater photography, polyclads can be a good subject to study, to describe and to find missing links in the evolutionary history.

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Kasagia sudhakari, a new species of spider crab from the southern continental shelf of Indian EEZ

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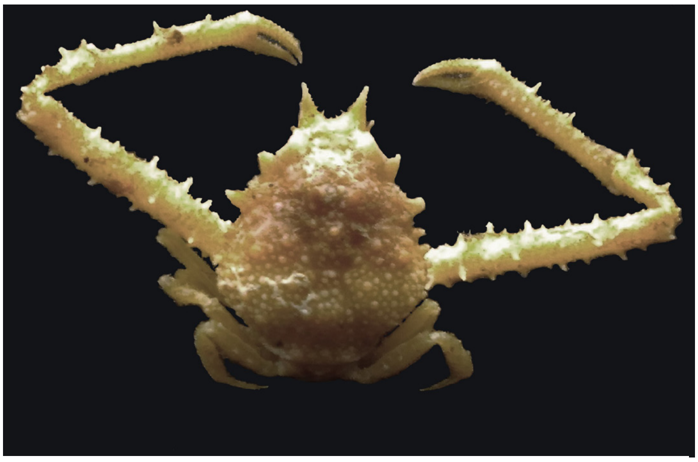
The shelf and deep-waters of the Indian EEZ are known to support wide array of decapod crustaceans, as evident from recently published taxonomic descriptions as well as those in the process of being described. One such recently described species is *Kasagia sudhakari* Padate, Hashim & Ng, 2019 collected during FORV Sagar Sampada's cruise number 340 at 109 meters depth off Cape Comorin (Kanyakumari), India.

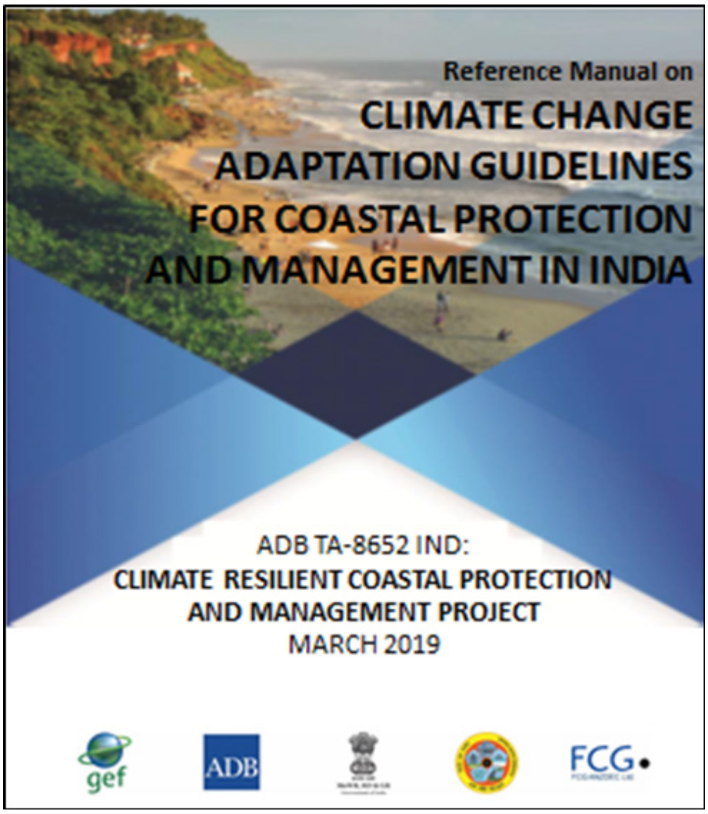
It is a spider crab (Family Majidae) belonging to a rare genus *Kasagia* Richer de Forges & Ng, 2007. It is characterized by "a proportionally broad carapace with divergent pseudorostral spines, the supraorbital eave separated from the postorbital spine, prominently long lateral branchial tubercles, a triangular inter-antennular spine, a conical hepatic lobe, a short cheliped, presence of several short granules on ambulatory merus, and a slender male first gonopod with the tip slender and the margin folded with the disto-lateral opening appearing in sternal view". The species is named in honour of distinguished marine scientist and the current CMLRE Director and OSI President, Dr. M. Sudhakar.



Kasagia sudhakari

The crabs of the genus *Kasagia* are known to be inhabitants of hard-bottomed steep continental slopes. The above discovery suggests that more dedicated surveys of the continental shelves and slopes of the Indian EEZ would definitely yield rare and interesting species of decapod crustaceans from these pristine habitats.

Climate change and adaptation in coastal management



India has made another breakthrough in the battle against climate change with the new 'Reference Manual Climate Change Adaptation Guidelines for Coastal Protection and Management in India'. The Guidelines are critically important when sea level rise, more intense storms and rainfall, heat waves and human displacement are looming large. This first of this kind document for India greatly advances the country's preparedness at the right time when India is a key participant in global initiatives against climate change. It may reduce the multi-billion-dollar burgeoning budgets needed to protect the coast while aiding the millions of Indian coastal inhabitants

More than an engineering manual, the Guidelines recognize the links between economic, physical, social and governmental complexity in handling climate change. The concept promoted is that solutions may occur only when all facets are improved simultaneously. Fundamentally practical solutions to inhibit coastal erosion and sustain life and livelihood are presented with learning from historical case studies, modern scientific knowledge and best global practices. While the Guidelines are focused on India, this important document provides useful assistance to all countries with shorelines exposed to climate change.

Strategies to cope with climate change

For the first time in India, the Guidelines confront the need for 'grand scheme' coastal solutions. These are projects which aim to fundamentally alter the beach and shoreline dynamics to enable sustainable and stable shorelines. They break away from traditional thinking about fixing a local problem, while hoping to have no downdrift impacts. 'Grand schemes' go well beyond this, aiming to confidently alter the sediment dynamics in a full sediment cell. Such schemes will need quality multi-disciplinary science with effective planning. The Guidelines suggest that 'grand schemes' may be the only cost-effective sustainable solution under climate change in many critical cases.

Guidelines in practice

A novel tool called the 'Environmental Softness Ladder' has been introduced to rank the environmental impact of a project. The goal is to formalize the link between least environmental effect and best protection solution. The Guidelines highlight the value of low environmental impact, not only to help the environment, but to show that minimizing environmental effects will improve project success, downdrift impacts and sustainability. The document shows that the best results arise with nature's solutions, such as sandy beaches and dunes or offshore reefs and islands.

The 'Environmental Softness Ladder' allow decision makers to make sound conclusions about the coastal protection alternatives. A series of data-entry forms help the proponent and the approval committees to make decisions founded on well-presented information using a more formal system. The 'C-Assessment' scheme rationalizes decisions and embodies the key elements of the Guidelines. The Climate Change Adaptation Guidelines will be handy for planning, design, submission, appraisal, monitoring and evaluation of coastal protection and management projects.

How is the document structured?

The 'Reference Manual on Climate Change Adaptation Guidelines for Coastal Protection and Management in India' was prepared for Ministry of Water Resources, River Development and Ganga Rejuvenation Central Water Commission' (MOWR,RD&GR) with Central Water Commission (CWC) as focal point under an Asian development Bank Project (ADB TA-8652 IND) supported by the Global Environment Facility (GEF). The Report was prepared under the guidance of National Technical Committee (NTC) and a Panel of Experts appointed by MoWR,RD&GR. The Reference Manuel is presented in two volumes:

Volume 1 introduces more than 50 suggestions (guidelines) for sustainable coastal management under climate change. An explanation, case studies and the basis for each suggestion are given, with a comprehensive discussion about climate change and coastal impacts. For convenience, the suggestions are grouped under nine headings from administrative to island territories.

Revetment, vegetation and wide beach at Navabag, Vengurla, Sindhudurg, Maharashtra facilitating flood protection, fishing operations, recreation and tourism

Volume 2 is a reference manual, with 19 appendices, each focused on an important topic, such as engineering solutions, economics, physical dynamics or coastal planning and regulations. It presents the first summary of Indian scientific documentation in the area of coastal science and engineering with the goal of encouraging more coastal scientific research.

Who are users of the guidelines?
The Central and State Governments and other agencies can now uniformly plan protection schemes against coastal flooding and erosion. The guidelines provide clear instructions on the selection and design of coastal protection schemes. Towards this data on projections of climate change parameters are now available to coastal planners in the India-WRIS portal of CWC free of cost for the first time.

Target group	Potential use
Engineers and managers involved in the planning, design and construction of coastal protection measures	Designing appropriate climate resilient solutions, choosing options, preparing detailed project reports and monitoring project implementation
Administrators and decision makers at the national and state levels	Evaluation of schemes, approvals, allocation of resources and cost optimization
Environmental scientists and managers	Scope of environmental appraisal, design and implementation of monitoring and evaluation of environmental impacts, corrective measures and performance appraisal
Researchers, academicians, private parties and sector consultants	Recommendation of technologies, designs, tools and methods, project implementation and monitoring modelling, data generation and other important areas for future research
Communities	Awareness generation, promoting community action and participation in maintenance
University and high school students	Education and awareness about the impact of climate change on the coast

This Reference Manuel can be downloaded from http://cwc.gov.in/CPDAC-Website/ index.html.

Reference to the Report is:
Black K.P., Baba M., Mathew J., Chandra, S., Singh S.S., Shankar R., Kurian N.P., Urich P., Narayan B., Stanley D.O., Parsons, S., and Ray G. (2019) 'Reference Manuel on Climate Change Adaptation Guidelines for Coastal Protection and Management in India' (Eds: K.P. Black, M. Baba and J. Mathew), prepared by FCG ANZDEC (New Zealand) for the Global Environment Facility and Asian Development Bank, Volumes 1 (72p) and 2 (335p).

OSI Activities

Kerala deluge and 2018 monsoon

The Ocean Society of India – Kochi Chapter in the wake of the very active southwest monsoon and the resulting unusual flood in Kerala organized a 'Panel Discussion' in Kochi jointly with Centre for Marine Living Resource and Ecology (CMLRI – MoES) and National Institute of Oceanography (CSIR-NIO, RC) on 5th October 2018. The strong winds and large waves from the time of Ockhi cyclone of Nov 2017 and through the monsoon of 2018 resulted in severe erosion of Kerala's beaches and flooding of the coastal belt. The August extreme rainfall activity caused in addition to the floods in the coastal plains, huge landslides in the higher reaches. The fury of current year's monsoon rains followed by overflowing rivers and dams, landslides and inundation of low-lying areas resulted in the loss of more than 480 lives and displacement of over one million people in Kerala.

Though Kerala bravely managed the calamity, several scientific, technological and policy- related questions are coming up to the forefront. An expert panel discussed the various aspects in the Panel Discussion with a major objective to analyse scientifically the causative factors for the 2018 monsoon and its impacts in Kerala and came up with a few recommendations for future action. Altogether about 50 participants from various institutes from India attended and actively involved in the deliberations and discussion.

Dr.M.Rajeevan, Secretary, Ministry of Earth Sciences (MoES) in his inaugural address not only appreciated the efforts of OSI Kochi Chapter, CMLRE & NIO in organizing such a panel discussion but also offered full support for the future action plans. The Secretary expressed his concern over the loss of life, huge damage to land, water and infrastructure. He has also expressed the inadequacy faced in areas such as management of dams, absence of precise mapping of land slide prone areas and lack of proper awareness in maintaining ecosystems. He hoped that the Panel Discussion will come up with recommendations for future action. Dr.M.Sudhakar, Director CMLRE welcomed the panellists and others attending the Panel Discussion.

Dr.M.Baba, President of Kochi Chapter of OSI chaired the session. In his introductory remarks he requested the panellists that the discussions should be focussed on the scientific and technical aspects. He wanted the panel to come up with specific recommendations on the studies and actions required for mitigation and also measures for preparedness for future calamities. Then he invited the six experts representing various fields to give the key note presentations. He requested the rest of the expert panel members to take active part in the discussions.

The recommendations emerged out of the day long discussions were submitted to the various agencies for further action.

Ocean Science Outreach

The Ocean Society of India conducted awareness programme at Sree Narayana College, Cherthala on 12/01/2018 for school children as part of its outreach programme. The function started with an inauguration followed by three talks : Prof. Dr. K. S. Purushan, Former Dean Fisheries, KAU, gave a talk on Oceans, its importance in economy, food security, climate; Dr.C V K Prasad Rao, Former Chief Scientist of NPOL delivered a talk on climate, weather, calamities in ocean, tsunami, ockhi and ocean current; Dr.Dhanya Viswam, Assistant Professor, S N College delivered a talk on chemistry of sea water.

Film show on Oceans brought from CSIR – NIO and CMLRE was conducted from 10.00 am to 4.30 pm. Exhibition of oceanographic equipments and scientific charts attracted the students of the college and also students from outside.

Elocution competition was conducted for selected students of standard 10th to 12th from different schools on OCEANS. The best student was given a memento and an appreciation certificate. A drawing competition was also conducted for students and best drawings were selected and given a memento and an appreciation certficiate.

The Inaugural programme was chaired by Dr. C. Revichandran, OSI Joint Secretary and inaugurated by Prof. Dr. K. S. Purushan, Former Dean, Faculty of Fisheries, KAU & Former Member, Fishermen Debt. Relief Commission, Govt. of Kerala. Dr. K. B. Manoj, Principal, S. N. College was the chief guest. Prof. PrasadaRao, G C member. OSI offered the falicitation. Dr.MeeraVasundhathi, General Convener offered welcome address and Prof. Dr. K. V. Jayachandran, G. C. Member, OSI expressed vote of thanks.

Total number of registered participants: 138, including Students from Schools, First year UG students of the Departments of Chemistry and Geology.

World Ocean Day

World Oceans Day is observed to remind everyone about the major role the oceans play in everyday life. It is described as the lungs of our planet, providing most of the oxygen for the biota to breathe. Oceans provide food, medicine, huge employment potential, conserve precious cultural heritage, conducive environment for biota, maintenance of ecological balance, control weather systems and many other inevitable services. The anthropogenic activities has damaged the ocean beyond the level of tolerance and therefore, most of the oceans are under threat of sustainability and hence urgent interventions warranted. Recognizing the seriousness of the issue and the pressing demands from millions of people and thousands of R & D institutions and academia around the world the United Nations General Assembly passed a resolution in December 2008, officially recognizing 8th June as World Oceans Day each year. In this background the world ocean day is being celebrated to conserve oceans.

Ocean Society of India (OSI) observed the world ocean day on 8th June 2019 at Mararikkulam Beach. The programmes conducted were: Interactive Sessions on various aspects of oceans and beach cleaning. The interactive awareness programme on oceans was conducted in which 90 students from High School to College level, Active fishermen who are deeply involved in ocean conservation, teachers, officials from CMLRE , NIO, NPOL, Universities, NGOs participated. The sessions were successfully handled by Dr. M. Sudhakar, President of OSI; Prof. Jayachandran, Vice-President of OSI; Dr. C. Revichandran, General Secretary OSI; Dr. Baba, GC member, OSI; Dr. Prasada Rao, GC member, OSI; memebrs of OSI, namely, Dr. Santha Devi, Dr. Kesava Das, Dr. Sajeev, Dr. Anand; Mr. Isaac, native participant, Mr. Sebastian, a teacher, Mr. Girish, Manager,Marari Beach Resort and others. Marari Beach cleaning was conducted during the afternoon and all of them participated and collected huge plastic waste and the waste was disposed for recycling by Marari Beach Resort. About 100 kg of plastic waste was removed from the beach within a period of 1 hour.

OSI acknowledge the great support from CMLRE, Governing Council of OSI, School students from S N College, VHSS Kanichukulangara, St. Augustine's School, Active fishermen and teachers. The support given by Marari Beach Resort andf the financial support given by Central Government Officers Association is gratefully acknowledged.

Ocean Modeling Workshop for Students and Research Scholars (OSIMOD 19)

It is a known fact that ocean modeling is an important area of research and it has become more relevant now in this era of climate change. Ocean Society of India (OSI) has been encouraging young students and scholars in one way or other by providing opportunities to them to enhance their knowledge base on oceans. This workshop is yet another step in that direction. OSI and Kerala University of Fisheries and Ocean Studies (KUFOS) jointly organised a workshop on Ocean Modeling for Students and Research Scholars (OSIMOD 19) at KUFOS, Panangad, Kochi during 11-14

June 2019. The sole objective of it is to provide hands-on experience with two important contemporary ocean models, namely, Simulating WAves Nearshore (SWAN; an ocean wave model) and Regional Ocean Modeling System (ROMS; ocean circulation model) which are used for operational ocean forecasting purposes at many places over the globe. Two of our senior life members of OSI, Prof. Prasad K Bhaskaran and Prof. Arun Chakraborthy, both from IIT, Kharagpur have demonstrated the above two models to the participants of OSIMOD 19.

The programme was inaugurated on 11 June 2019 (F/N) by Prof. A. Ramachandran, Vice-Chancellor, KUFOS. Dr M. Sudhakar, President, OSI presided over the function. Vice- Chancellor, KUFOS appreciated the efforts made by OSI and extended full support for similar activities in future also. President OSI emphasised that the ocean and atmospheric models are more accurately predicting the extreme weather events and monsoon. Dr C.V.K. Prasada Rao, Prof. S. Suresh Kumar, Prof. Prasad K Bhaskaran and Dr C. Revichandran spoke on the occasion. Thirty-three (33) PG students as well as research scholars from academic and R&D institutions in India have participated in the workshop, covering, KUFOS, Pondicherry University (Port Blair), CUSAT (Cochin), Goa University, Andhra University, NIT (Calicut), CMFRI (Kochi), NIO (Goa), NIO (Mumbai), NIO (Kochi), NERCI (Kochi), NRSC (Hyderabad), IOM (Chennai), NCSCM (Chennai) and SRMIST (Chennai).

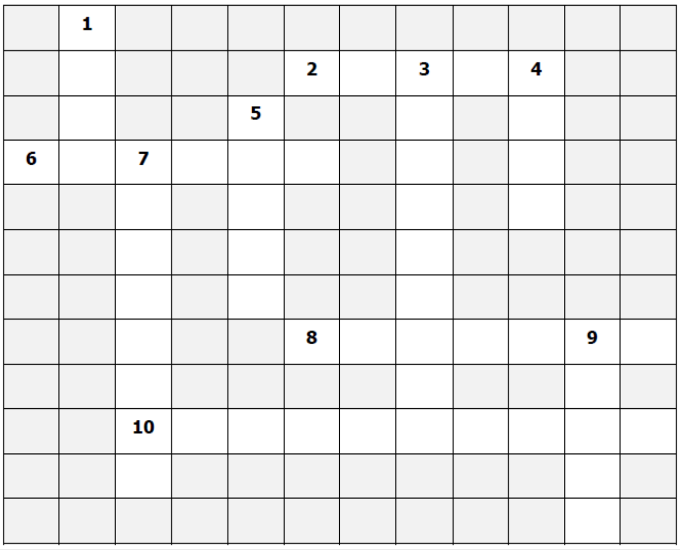
One of our senior members of OSI, Shri S Ananthanarayanan, DS & Former Director, NPOL graced the valedictory function on 14 June 2019 (A/N) and distributed the certificates and mementoes to the course participants. Dr C V K Prasada Rao, convener OSIMOD 19, Prof. K V Jayachandran, Vice-President, OSI, Dr C Revichandran, General Secretary, OSI, Prof. Arun Chakraborthy, IIT, Kharagpur and Prof. S Suresh Kumar were also present during the valedictory. The feedback received from participants was quite encouraging and they wish to have more workshops of this nature in future also.

National Seminar on Climate Change and Coastal Ocean Processes (CCCOP-2019)

The Ocean Society of India (OSI) organized a National Seminar on "Climate Change and Coastal Ocean Processes" (CCCOP-2019) at Centre for Atmospherics Sciences, Indian Institute of Technology Delhi during 4-5 July 2019. The Seminar was co-sponsored by India Meteorological Department, Government of India. It was a great success in fulfilling its aims with the contributions from eminent scientists, researchers and students from a wide range of institutes across the country. There were a total of 13 lead talks and 30 presentations in the seminar. There were a total of 6 sessions in the seminar covering (i) Climate change and coastal hazards, (ii) Coastal currents, waves and tides, (iii) Coastal erosion/accretion processes and their modeling, (iv) Coastal ecosystems and their modelling, (v) Climate change impacts on coastal ocean processes, (vi) Adaptation to coastal hazards and climate change impacts.

Crossword

The clues for the Earth Science Crossword can be traced to the earlier issues of Ocean Digest or ongoing events. Enjoy.



ACROSS

2. Arabian Sea witnessed this super cyclonic storm during October-2019 (5).
6. The lander of ISRO's second lunar exploration mission Chandrayaan-2 was named as (6).
8. El Niño develops in this ocean (7).
10. This throughflow provides a low-latitude pathway for warm, fresh water to move from the Pacific to the Indian Ocean (10).

DOWN

1. This rain shadow desert is formed by the Tibetan Plateau blocking precipitation from the monsoon flow (4).
3. During this process a cohesive slab of snow lying upon a weaker layer of snow fractures and slides down a steep slope (9).
4. Nicknamed "The Last Ocean" it is the southernmost sea on the planet Earth (4).
5. Agreed upon in 2015, this agreement aims to keep global temperature rise well below 2degC pre-industrial levels and to pursue a path to limit warming to 1.5degC (5).
7. Also known as "The Black or Japan Current" it is a north-flowing ocean current on the west side of the North Pacific Ocean (8).
9. First country in the world to mandate curriculum on climate change for school students (5).

Compiled by Bhupendra B. Singh