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Institutional Report

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Introduction

The Ministry of Earth Sciences (former Department of Ocean Development) had established a Vessel Management Cell (VMC) at Kochi during 1989 primarily for the running and management of the Fishery Oceanographic Research Vessel FORV *Sagar Sampada* with a staff strength of about 15. In 1998, the VMC was elevated to an attached office, “Center for Marine Living Resources and Ecology” with the additional mandates of implementing the national Marine Living Resources Programme (MLRP), co-ordination of Southern Ocean Fishery Programme and establishment of MLR Data and Referral Center. Since then, with the growth and diversification of research activities related to these mandates, the operational needs of CMLRE have grown proportionately. At present, CMLRE has a strength of 10 scientists and 16 supporting staff.

The Marine Living Resources Programme (MLRP)

The core objective of the MLRP has been to, (i) delineate and quantify marine living resources of the country’s exclusive economic zone (EEZ), (ii) to understand the complex environmental regimes influencing their distribution, and (iii) conduct R&D activities related to marine living resources. The programme was initiated in 1998, and administered by CMLRE through various multi-institutional linked projects, running in tandem with the Governments Five-year Plan. The research activities of the MLRP is made possible through the effective utilization of the Fishery Oceanographic Research Vessel (FORV) *Sagar Sampada*, a 72 m OAL ice-strengthened vessel, commissioned in 1984 and managed by CMLRE.

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Between 1998 and 2007 the focus of the MLRP was on establishing baseline information on the distribution and abundance of marine fauna, including phytoplankton (including harmful algae), zooplankton, fishery resources (particularly deep-sea demersal fishes and organisms of the deep-scattering layer), benthos and marine mammals within the Indian EEZ, and to establish the key environmental factors affecting their distribution. With these objectives in mind, continuous monitoring of environmental factors and marine fauna was done at pre-fixed stations in the coastal and open-ocean regions of the EEZ. These monitoring activities continued from 2007 to 2012, and in addition, the task of integrating data collected through the MLRP was taken up, which resulted in the generation of specific data products, viz. (i) Climatological Atlas of the Indian EEZ, which depicts the seasonal variations in the environmental factors, as well as primary and secondary productivity in the region, (ii) CD-ROM on Marine Mammals, which document their distribution and migratory routes in the Indian EEZ, (iii) CD-ROM on the Zooplankton of the Andaman and Nicobar region, and (iv) Monograph of Bothid (flatfish) eggs and larvae of Indian Ocean. The CMLRE Data Centre currently archives all data and information gathered through FORV surveys. With the initiation of Indian Ocean Biogeographic Information System (IndOBIS) in 2009, CMLRE has been recognized by the Intergovernmental Oceanographic Commission (IOC) as the regional OBIS node for the Indian Ocean.

The present research emphasis of CMLRE is structured as follows:

1. Monitoring and Modelling of Marine Ecosystems (MMME)
2. Resources Mapping of Deep-Sea & Distant Water Fishery (DS & DWF)
3. Integrated Taxonomic Information System (ITIS)
4. Southern Ocean MLR (SO-MLR), and
5. MLR Technology Development (MLR-TD)

Monitoring and Modelling of Marine Ecosystem (MMME)

The marine realm acts as a dynamic environment for diverse organisms which carry out a vast variety of

functional roles as part of global-scale biogeochemical pathways. Marine phytoplankton are responsible for half of all primary production in the world, and energy is transmitted across complex food-webs to top-level consumers which include commercially important fishes. Remineralization of vast quantities of organic matter (of terrestrial as well as marine origin) is done by microbes both in the water columns of the ocean as well as on the sea-floor. Being completely land-locked from the north, the Indian Ocean has a unique set of climatological and environmental characteristics, which garners much scientific attention with reference to physical, chemical as well as biological aspects. Coastal upwelling, convective mixing, occurrence of eddies, seasonal sub-surface hypoxia, perennial oxygen minimum zones (OMZs) etc. occur in various parts of the EEZ, and have profound impacts on the fauna and biological processes. The northern Arabian Sea is identified as a major region for emission of greenhouse gases, owing to a combination of environmental and biological processes. From a biological standpoint, continuous monitoring of fauna and environmental factors is key to understanding the role of organisms in biogeochemical processes of the region. Strong baseline information is essential to enable modelling of the ecosystems and for predicting long-term changes in structural and functional aspects of communities in response to natural and anthropogenic influences.

Monitoring and Modelling of Marine Ecosystems (MMME) within the EEZ is presently one of the main activities of CMLRE that addresses various aspects of: (i) environment and productivity patterns, (ii) surveillance and prediction of harmful algal blooms, (iii) marine benthos, (iv) biological food-web dynamics towards the prediction of pelagic fishery, and (v) time-series biogeochemical studies off Kochi.

The studies have provided following major results:

Delineation of major Ecosystems of the Indian EEZ

Six major ecosystems have been delineated in the Indian EEZ, viz. Northeast Arabian Sea, Southeast Arabian Sea, Lakshadweep Sea, Northwest Bay of Bengal, Southwest Bay of Bengal and the Andaman Sea based on differences in physical processes, varying chemical and biological responses.

Time-series Biogeochemical Studies in the Eastern Arabian Sea

This is the first time-series study off Kochi which tracked upwelling (for one year) from its evolution, propagation to decay on the entire continental shelf. The study although found the signals of upwelling reaching inner shelf by May, importantly its onset at the shelf entrance in the deeper layers occurred at least 3-4 months earlier (January-March). Such an early onset suggests its triggering by the remote forcings, followed by propagation by currents and winds. Shelf oxygen saturations (hypoxic conditions) beyond 25 km from the coast remain more or less unaltered before and after the large developmental activities which took place along the west coast of India in the last few decades. The anthropogenic impact is seen mostly limited within the inner shelf region. Unlike in the south, the shelf region off the central west coast of India experienced anoxic conditions associated with upwelling and monsoon production, which affects pelagic fishery potential. The hypoxic-anoxic variation is mainly influenced by the initial oxygen concentrations between the central and southern regions. The production of global warming gases is at peak during summer upwelling.

Harmful Algal Blooms

A total of 448 species of micro algae have been recorded from the Indian EEZ thus far, of which 86 were bloom forming and about 45 were toxic species. Analyses of centennial changes of these algal blooms show that their occurrences increased significantly post-industrial growth. During 2008-2012, at least 27 such algal bloom occurrences were noticed. Extensive blooms of green *Noctiluca* is recurrently occurring during winter/spring inter-monsoon seasons in the north-eastern Arabian Sea. Major hot spot regions for these harmful algal blooms were identified. A species specific satellite algorithm to *Noctiluca*, diatom and mixed bloom occurrence was developed.

Closed Fishing Season and Shelf Benthos

Studies on macro-benthic standing stock and community structure during one-year time-series study off Kochi and in particular the closed fishing (trawl ban) season between June (pre-ban) and August (post-ban) indicate increased abundance, biomass and species richness from the pre-ban (monsoon onset)

to post-ban (monsoon peak) period. The increase was prominent in the active trawling area (30-50m depth) wherein the density of polychaetes larvae in the water column and juvenile polychaetes in sediments peaked during post-ban period. Macrofauna benefitted from the trawling ban off Kerala during the southwest monsoon, which coincides with the breeding season of many of the polychaetes. The recovery of macrofauna over the trawl-ban period is ecologically significant, not only for maintaining ecological balance but also because they are important sources of food for commercially important fishes.

Benthos of the Eastern Arabian Sea Under Oxygen Deficient Conditions

Regions impacted with seasonal hypoxia on the eastern Arabian Sea shelf recorded low abundance of macrobenthos with dominance of opportunistic polychaete species, which are well-adapted to hypoxia. Other fauna such as crustaceans and echinoderms, which are most vulnerable to low-oxygen, were nearly absent. The intensity of the Arabian Sea oxygen minimum zone (OMZ) and its influence on benthos was highest between 200-500m, particularly towards the north, where standing stock of fauna was lowest.

Maximum Sustainable Fishery Yield (MSY)

Integrating satellite and *in-situ* data on extensively collected various biological variables i.e. primary, secondary and benthic production, and following Trophodynamic modelling approach, MSY from the entire Indian EEZ was estimated to 4.32 million tons per year.

Species new to Science

Nine new species of marine benthos have been discovered from the Indian EEZ.

Resources Mapping: Deep-Sea & Distant Water Fishery (DSDWF)

Deep sea and distant water fishes are rapidly gaining importance as potential fishery resources, the reason being that the inshore fishery alone can no longer satisfy the growing demand for fish. Exploratory surveys conducted in deeper waters of the EEZ pointed out the presence of unexploited deep sea fish resources outside the shelf area/continental slope

region, which have immense scope for commercial scale exploitation. Advisory on long term sustainable exploitation of these resources will be possible upon obtaining adequate details of the stock size, gear selectivity parameters, migratory routes and growth parameters. The studies under this scheme include (i) Mapping of demersal fishery resources between 200 and 1000m depth zones of Indian EEZ, (ii) Studies on the Myctophid resources in the central Arabian Sea, their harvest and post-harvest product development technology, and (iii) Tuna Fishery Forecast System (TUFFS). The major achievements are as follows:

- Digital map of trawlable grounds along the Indian EEZ was prepared based on the data compiled from 9th plan to till now.
- Terrace off Trivandrum (1000 m depth region) in the southeastern Arabian Sea found to be supporting unique deep-sea biodiversity in terms of its species composition and average faunal size. A total of 80 species were recorded with relatively high density from this bathyal region.
- Length-weight relationship of 11 deep sea fishes from shelf region of Bay Bengal and Andaman waters were established.
- Established the relationships between fish size and otolith size of four deep sea fishes from the southeastern Arabian Sea.
- 19 new records of deep sea fishes and 1 new record of crab were observed from Indian EEZ.
- Survey in the central Indian Ocean found 20 species of myctophids and almost 55 species of other midwater fishes.
- A catalogue depicting the Myctophid species in the Indian waters was prepared with details of thirteen species including 2 new species.
- Near reef abundance and on-off shore distribution showed larval occurrence of the Family Scombridae in the Lakshadweep waters.

Integrated Taxonomic Information System (ITIS)

The Integrated Taxonomic Information System (ITIS) is a continuing program under MLR, initiated mainly for consolidating the taxonomic information gathered so far through various MLR projects, viz. Environment & productivity pattern, Harmful Algal Bloom, Benthic

productivity, Deep sea & demersal fisheries and marine mammals. This program is planned to address (i) Indian Ocean Biogeographic Information System (IndOBIS) for maintaining species records, (ii) Census of Marine Life (CoML) through DNA bar-coding for inventorying marine organisms and to assess the change in biodiversity, distribution and abundance of species from past to future, (iii) archival of oceanographic data and generation and dissemination of specific data products for societal benefit through FORV Data Centre, and (iv) archival of rare deep-sea specimens collected at FORV Referral Centre. The major accomplishments include:

- A comprehensive database containing about 1,06,033 occurrence records of more than 6500 marine species have been created with complete details of location, depth, taxonomic classification and hydrographic data. The entire dataset is published on-line through distributed network protocol Internet Publishing toolkit (IPT) in internationally acceptable format (DARWIN Core II) and is available at Ocean Biogeographic Information System hosted by IODE/IOC program.
- 1094 voucher specimens of deep sea organisms which include microalgae (53), polychaetes (464), fish larvae (252), echinoderms (70), gastropods (20), decapods (39), deep-sea pycnogonids (05), deep-sea fishes (183) collected through FORV *Sagar Sampada* are maintained at FORV Referral Centre.
- New record of *Ascorhynchus levissimus*, a giant species of deep-sea pycnogonid, reported for the first time from Indian Ocean.
- Totally 198 DNA barcodes have been created for deep sea fishes, shrimps, crabs, venomous & poisonous fishes and they were submitted to NCBI. New records of deep-sea crab (*Lyphira perplexa*), cephalopod (*Spirula spirula*), sea-pen (*Gyrophyllum* sp.) and sea spider (*Ascorhynchus levissimus*) were identified and barcoded.

Archival of all data collected onboard FORV *Sagar Sampada* since 1998 till now has been made under FORV Data Centre. The data includes weather parameters, vertical profiles on physical oceanographic parameters, acoustic data from multi-frequency echo sounders, nutrients, dissolved oxygen,

chlorophyll, species abundance data of micro & meso-zooplankton, fish eggs/larvae, benthos, deep scattering layer and deep sea demersal fishes. In compliance with the National Data Exchange and Security Policy of the Government of India, the data is also archived at INCOIS, the National Archival and Dissemination Centre for all Earth Science related data.

Southern Ocean MLR

Taking into consideration the large scale exploitation of the Southern Ocean resources and its possible impact on this delicate ecosystem, the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR) was established by the Antarctic Treaty Consultative Party (ATCP) in 1982 with its headquarters at Hobart, Australia. The prime objectives of CCAMLR are the conservation of living resources of Antarctica while permitting sustainable levels of exploitation of resources. India is a Member of CCAMLR and the CMLRE represents the Ministry in the CCAMLR related activities. Broader objectives under this activity include (i) documentation of planktonic compositions, fish eggs and larvae, food-web dynamics, and sea birds & whales along the various front and zones, (ii) experimental Krill trawling and its product development, (iii) promote Indian fishing industry to utilise these distant water resources, (iv) Census of Marine Life and bio-regionalisation, studies on microbes including extraction of bioactive molecules, and (v) CCAMLR matters.

The CMLRE has participated in the Southern Ocean expeditions conducted by ESSO-NCAOR during 2009, 2012 and 2014 and the major achievements include:

- Documented the distribution patterns of meso-zooplankton particularly pelagic amphipods in fronts and zones north & south of Agulhas retroflection front (ARF)/Southern subtropical front (SSTF). About 20 species of amphipods-with characteristic features of polar and subtropical species described.
- Benthic surveys along 200-300 m depth contours near Enderby Land revealed presence of 55 species of polychaetes, 5 species of echinoderms, 2 species of pycnogonids along with several species of crustaceans and bryozoans.

- Studied micro-plankton community at Subtropical front (STF) and Polar front (PF) during 2012, which revealed existence of different trophic pathways of energy transfer in these two regions. The study was continued in 2014, and the observed difference in production, phytoplankton community structure, grazing and senescence indices along with the changes in secondary consumers, strengthen the information on the disparity in food web structure existing at PF and STF.

MLR Technology Development (MLR-TD)

Basic information and technological knowhow on ornamental fish breeding and culture in the Lakshadweep has been generated through the efforts of MLRP during the past decade, the activities are towards technology transfer and commercialization. Under this scheme, efforts are being made to prospect for bio-active products development from marine organisms, and acoustic estimation of marine resources. The major achievements are:

- Standardised breeding technology for 5 species of clown fishes such as *Amphiprion nigripes*, *Amphiprion clarkii*, *Amphiprion percula*, *Amphiprion ocellaris*, *Premnas biaculateus* and 2 species of damselfish *Dascyllus aruanus*, *Chromis viridis*.
- The live feed for culturing clown fishes has been standardised with microalgae (*Nanochloropsis salina*, *Chlorella spp* and *Isochrysis*) and rotifer *Brachionus plicatilis*.
- In-situ spawning of marine ornamental shrimps has been achieved and its standardisation is underway.
- The breeding and spawning technology of ornamental fishes has been transferred to island communities through organizing intensive training programmes.
- The trained islanders were encouraged to form a Society (Marine Aquatech Fish-farmers Association-MATFA) under the Department of Women Welfare and Child Development, U. T of Lakshadweep Administration for rearing and marketing of juvenile fishes produced at hatchery.
- Biodiversity survey of marine ornamental fishes

and other invertebrates in Lakshadweep waters record many new species and occurrence of fishes and invertebrates.

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