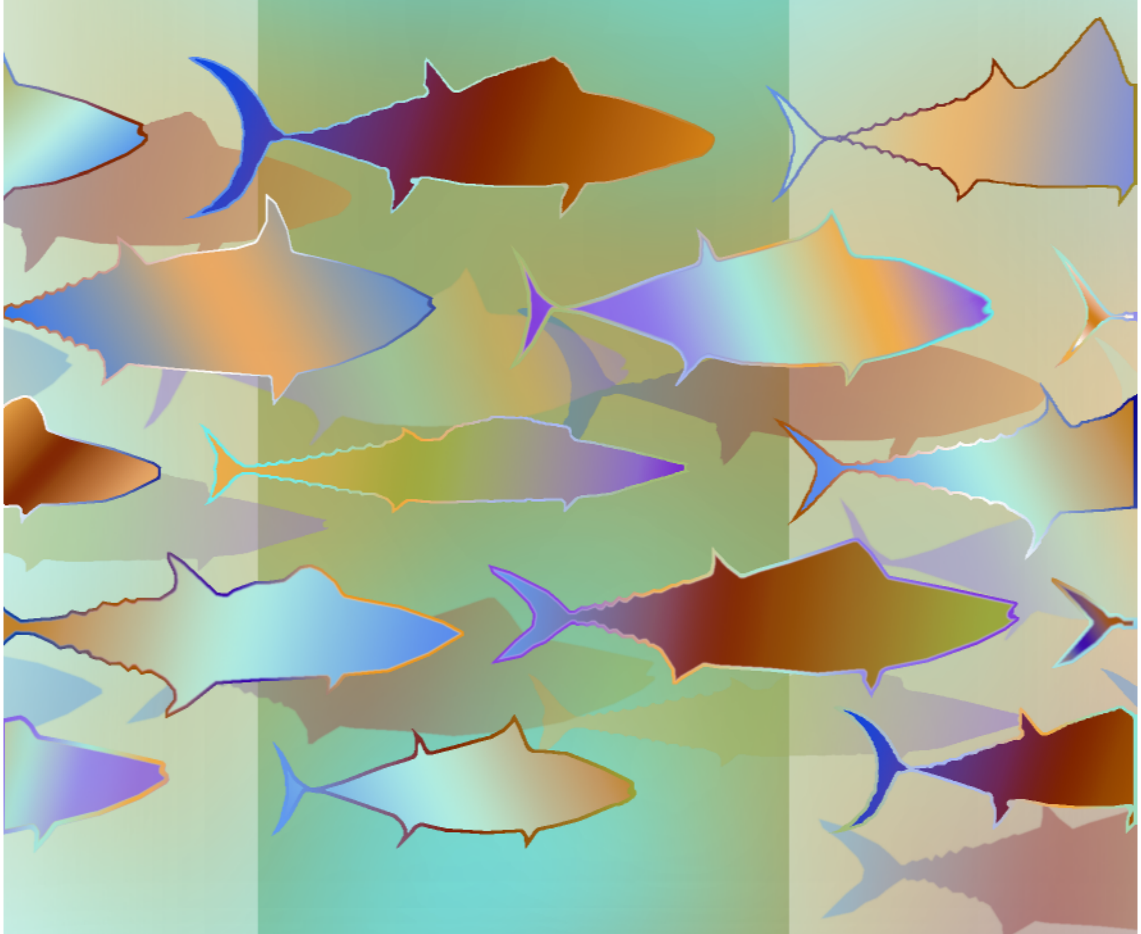
Status of Exploited Marine Fishery Resources of India



STATUS OF EXPLOITED MARINE FISHERY RESOURCES OF INDIA

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Environment and Forecasting

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1. Introduction

Studies on the characteristics of the marine environment are important in fisheries research as the conditions in the sea play a major role in the availability of fish. The fluctuations in the physical, chemical and biological oceanographic conditions have a profound influence on the periodic and seasonal migration of fishes in the sea. Research at CMFRI has strived to understand how these mechanisms work and how knowledge can be incorporated into the management and conservation of the nation’s marine living resources.

The scientific information on the physical, chemical and biological oceanography of the Indian Ocean was least known till the commissioning of the International Indian Ocean Expedition (IIOE) in the 1960s. Later the Central Marine Fisheries Research Institute, National Institute of Oceanography and various Universities have also added valuable information on the Indian Seas by employing modern fisheries and oceanographic research vessel. Hydrographic data were collected for 3,300 stations during the cruises of M.V. Pratap, M.O. Kristensen, R.V. Kalava and R.V. Varuna from 1957 to 1965 along the west coast of India. The studies conducted under the Joint Global Ocean Flux Studies (JGOFS) programme (1992-97) have gathered some new scientific information from the Arabian Sea. The major parameters which have bearing on the marine living resources are temperature, salinity, upwelling, primary and secondary production. Our understanding of the role of the parameters on the marine living resources is summarized below.

2. Environmental factors

Temperature

Temperature is one way we measure ocean variability, but it is also an indicator of more complex ocean processes. Changes in surface seawater temperature affect the abundance and diversify of plankton, which are food for small fish. Most fish species have a fairly narrow range of optimum temperatures related both to the species basic metabolism and the availability of food organisms that have their own optimum temperature ranges. In the Indian EEZ, the mean surface temperature (ST) is about 29^0C during summer (April-May). With the advancement of the summer monsoon (South West monsoon) over the Arabian Sea and Indian Penninsula, the ST cools down, reaching 25^0C during August – September. The variations in the ST are considered as an indicator of fish abundance. The ST and ocean frontal zones, where temperature of water suddenly changes are used in locating the potential fishing zones using remote sensing techniques (Fig. 1). Intensive validation programme of Potential Fishing Zone (PFZ) advisories carried out by CMFRI around Minicoy Island and Kerala revealed positive relationship between PFZ and occurrence/abundance of commercially important pelagic fishes (For details, please see under section Forecast of marine fishery resources).

Below the surface waters, the temperature drops rapidly, forming a layer called the thermocline. In general, the thermocline in the Indian sea is shallow during the southwest monsoon, moderate in the summer and deeper during winter. During June-September, the thermocline occurs between 30 m and 80 m depth of the south west coast and the Gulf of Mannar but it descends to 80 – 120 m during December – February. The availability of fish stocks in our inshore waters is related to the seasonal variations in the depth of thermocline influenced by the monsoon. The mackerel and sardine fishery along southwest coast of India starts with the onset of southwest monsoon. The thermocline is located very close to the surface during monsoon period and is deeply embedded during winter. The top of the thermocline is usually located at depths of 40-75 m during spring, 20-50 m during monsoon and 50 –100 m during winter. The thermocline intensity is about 1.3^0C/10 m during pre-monsoon season. It attains greater stability in monsoon, with an intensity of about 1.7^0C/10 m and the intensity is moderate, with 1.5^0C/10 m, during winter.

During southwest monsoon (June-September) when the thermocline moves towards the surface and coast along the southwest coast of India, there is a concentration of both pelagic and demersal fishes. Tunas gather around the areas of upwelling and in the areas where the thermocline is shallow. In Lakshadweep waters, large shoals of skipjack tuna are found during December when divergence and shallow thermocline occur. Strong thermocline generally keeps the pelagic fishes like the coastal tunas and small pelagics above it and the demersal fishes below it, thereby forming a natural barrier in between. During purse seining, shallow and strong thermocline make fishery very effective, especially when the vertical depth of the gear is more than the depth of the thermocline.

The seawater temperature gradient such as thermocline is useful in commercial fisheries for (1) setting the depth of the long lines for tuna fishing, (2) setting the depth of the drift gill nets for shark and seerfish fishing, (3) determination of optimum depth of midwater trawling, and (4) deciding the operational pattern of the purse seines.

Salinity

The monthly mean sea surface salinity in the southeastern and central eastern Arabian Sea indicates two peaks, one during May –June before the onset of southwest monsoon and another during September-October immediately after the southwest monsoon. The monthly mean surface salinity varies from 32.5 ppt to 36.1 ppt. The salinity maximum characteristics of the tropical ocean are found at depths of 100 m to 150 m during northeast monsoon and 30 m to 50 m during southwest monsoon. The surface salinity is the highest at the Karwar and Ratnagiri section during May/ June varying from 35.6 to 36.1 ppt. Comparatively low saline waters (33.0 ppt) occupy the surface at Cape Comorin in December when the equatorial surface waters advect northwards. In general, the section north of Kasaragod exhibit comparatively higher salinity conditions than the southern sections. The northern region of the Arabian Sea (Mangalore to Ratnagiri) was reported as favourable for the mackerel fishery, while the southern region for sardine fishery. The reason attributed was the sudden increase in salinity occurring northwards (north of 13^0N) from the region off Mangalore during major part of the year. The higher salinity values in the northern regions appear to be more favourable for mackerel fishery than oil sardine fishery.

Upwelling

Upwelling occurs during certain seasons when the winds shift surface waters from the coast to offshore. The colder bottom waters, which are rich in nutrients, rise to the surface near the coast. This upwelling of bottom waters provides nutrients for the growth of microscopic plants and animals that fish feed on, thus promoting growth of the fish population. Upwelling takes place chiefly along the coasts of Peru, western North America, northwest and southwest Africa, Somalia, the Arabian Peninsula and Antarctica. In Arabian Sea, upwelling starts at the southern tip of the west coast by the end of May or early June and propagates northwards with time. This condition prevails until the end of August or early September and then the coastal upwelling subsides. Though upwelling seems to set in along the west coast of India around April- May, the most active period is June-September and the region where upwelling is most active is the south and central west coast of India. Upwelling is reported around Lakshadweep Islands during November/December and off Cochin, it starts by mid August, establishes by late September and ends by mid October. During upwelling, the oxygen minimum layer (0.5 ml^{-1}) emerges from 100 m to 150 m depth to the surface, especially in the areas between Quilon and Kasaragod. As a result, some fish population move in to the sallow surface waters while the others move offshore, away from the centre of strong upwelling. Pelagic fishes like mackerel, oil sardine and whitebaits avoid temporarily the areas of intense upwelling and tend to concentrate into dense schools close to the surface and the coast in the nearshore grounds, affording good catches. With the progress of monsoon and upwelling towards north, pelagic shoals also follow the trend and spawn intensely during June to September when there is maximum availability of larval food.

The economic benefit of upwelling is the large concentration of commercially important fishes such as oil sardine, mackerel and whitebaits in those areas. Most of the aggregating fishes are clupeids with short food chains. During upwelling chlorophyll a and productivity values go up from an average <0.5 mg m^{-3} and ca. 50 mg C m^{-3}/day respectively in January-April to 2.5 to >7 mg m^{-3} and >200 mg C m^{-3}/day in June-September. Diatoms form the bulk of the phytoplankton and consist of many species which commonly form blooms. During upwelling, phytoplankton bloom is followed by zooplankton abundance attracting commercially important fishes. During upwelling period, zooplankton biomass values of >1 ml m^{-3} are common and up to 12 ml m^{-3} have been recorded. Good correlation was reported between upwelling and zooplankton biomass at Cape Comorin, Quilon, Cochin, Kasaragod, Karwar and Ratnagiri.

Primary and secondary production

Primary production is the synthesis of new plant matter by floating microscopic plant components of the seawater through the process of photosynthesis. Most ocean animals depend -directly or indirectly- on these microscopic organisms for survival. The fishery for oil sardine and mackerel are entirely dependent on the blooms of phytoplanktons along the west coast of India. It has been noted that the first arrival of oil sardine along the west coast coincides with a diatom bloom and the migration of oil sardine are timed to coincide with two seasonal blooms of the diatom, Nitzschia oceanica. Along the southwest coast of India, the phytoplankton bloom is rich during the SW monsoon off the Trivandrum coast from January onwards and reaches the peak in May, but further north, off Calicut and northwards, the peak is attained in July-August and from September onwards, the phytoplankton bloom vanishes. The average primary productivity of the west coast of India within the surface and 50 m depth is 1.19 g C/m^2/day and it is equivalent to an annual gross production of 434 g C/m^2/year which is quite high compared to several other areas of the world. The productivity is high along the coast than along the edges of the shelf and the least outside the shelf. The reported average surface chlorophyll a (Chl a) for the Indian Ocean is 0.158 mg/m^2, where as the average values for the Arabian Sea and Bay of Bengal is 0.244 and 0.224 mg/m^2 respectively. Total phytoplankton population in the Arabian Sea when three seasons are combined is comprised of 86% diatoms followed by cyanobacteria (7%) and dianoflagellates (6%).

Zooplankton includes microscopic protozoans and such sea animals as copepods, water fleas, and jellyfishes, which constitute the secondary producers. Zooplankton forms the vital link in the pelagic food chain. Many microzooplankters also constitute the major food item of the larvae of most of the fishes. In the main upwelling areas of the west coast, between Kasaragod and Quilon, the peak of zooplankton occurs in July-August with another peak from October to December. The latter period is also the peak for the northern region between Karwar and Ratnagiri. In the Gulf of Mannar, the highest zooplankton production occurs in July and again in November - December. In general, the period from July to September is found to be the peak season for plankton production, with a fairly uniform concentration of plankton beyond the nearshore waters all along the coast. Fish larvae (ichthyoplankton) are abundant between May and September, with peak in July to September, moderate abundance in October and November and low abundance during December to April.

Primary productivity and phytoplankton biomass show definite seasonal patterns in the Arabian Sea. They are high during the southwest (summer) monsoon and part of the northeast (winter) monsoon, and are low during the inter-monsoon periods (Table 1). They also show north-south and east-west variability depending on physical events such as upwelling or winter cooling. The shelf areas of the Indian Seas, which sustain the bulk of fish production at present are on the whole, having a high rate of primary production (Table 2). Because of the constant replenishment of nutrients in the surface layers, the shallow waters are generally more productive.

Table 1. Average values of biological parameters for different seasons in the coastal waters from Arabian Sea, integrated for the upper 120 m, primary production, (m mol C m^{-2}/d) and other parameters (m mol C m^{-2}

Season	Primary production (m mol C m^{-2}/d)	Chlorophyll a (m mol C m^{-2})	Bacteria (m mol C m^{-2})	Microzooplankton (m mol C m^{-2})	Mesozooplankton (m mol C m^{-2})
Inter-monsoon	21	44	11	379	143
Winter	42	92	1	269	108
Summer	92	77	6	139	97

Source: Madhupradap et al., 2001.

Table 2. Primary production in the Indian seas

Geographical area	Primary production mgC m^{-2}/day		Net Production (Tonnes)		Total
	Upto 50m	Upto 100m	Upto 50m	Upto 100m	
West Coast of India	1,200	530	30 x 106	17 x 106	47 x 106
East Coast of India	680	200	10 x 106	7 x 106	17 x 106
Continental					
shelf upto 100m	na	na	na	na	64 x 106
EEZ (2.02 million km^2)	na	na	na	na	283 x 106

Source: Gopinathan and Balachandran, 2000.

Several attempts have been made to relate primary productivity to that of potential yield or optimum sustainable yield. From our EEZ of 2.02 million km^2, the total estimated production is 283 million tonnes of carbon. Therefore, the calculated harvestable fishery resource from our EEZ would amount to about 5.5 million tonnes (0.02% of the calculated primary production), both pelagic (70%) and demersal (30%) resources. Secondary production along the Indian coast ranges from 1.4 mg C m^{-2}/day to 57.3 mg C m^{-2}/day. The seasonal higher productivity in the eastern

Arabian Sea is found to be mainly through upwelling during summer and cooling during winter.

3. Forecast of marine fishery resources

There have been several attempts to correlate pelagic fisheries with seawater surface temperature, salinity, rainfall, upwelling, chlorophyll distribution etc. with very limited success. Environmental parameters and process such as wind driven upwelling, warm current, sea level and microbial loop in the coastal waters were reported to dominate the processes controlling the oil sardine fishery. It is reported that three major classes of processes are combined to influence our coastal pelagic fishery: (i) enrichment (upwelling, mixing, etc.), (ii) concentration (convergence, frontal formation, water column stability, etc.) and (iii) processes favouring retention within appropriate habitats.

Recently, remote sensing techniques have been used for forecasting the pelagic fishery resources. Temperature data from satellites have been used for many years to identify the distribution and magnitude of ocean currents and areas where different water masses meet in hydrographic fronts, which are known to be biologically highly variable. Satellite observations characterize environmental factors that affect fish habitat. Environmental parameters that are well measured by remote sensing include surface temperature, ocean colour, wind, chlorophyll a and current data. Advantages of satellite-based observation include the ability to image large areas at once, to discreetly observe a range of scales, to repeat observations frequently, and to make observations independent of weather.

Remote sensing data are used to derive information about chlorophyll concentration, primary productivity, bio-optical properties of coastal and estuarine regions, and ocean circulation features. Schools of pelagic fish are usually found close to areas high in Chlorophyll a, and close to the temperature fronts (where temperature of water suddenly changes). Ocean surface temperature (SST) and chlorophyll a distribution maps derived from satellites are routinely used in locating the potential fishing zones (PFZs), which help fishermen for getting good fish catch (Fig. 1). However, application of remote sensing to fisheries requires previous knowledge of habitat preference of the fish, biological quality of the waters, oceanography of the area, behaviour of a given species at various temperatures, and catch rates obtained under those conditions.

In India, the Marine Satellite Information Service (MARSIS) was initiated by the Department of Ocean Development and is co-coordinated by the National Remote Sensing Agency, as the nodal agency and the Central Marine Fisheries Research Institute as one of the participating agencies. The PFZ validation undertaken by the CMFRI by means of real time surveys for ground truth data reported significant correlation between the SST and the occurrence and or abundance of pelagic fish, as evidenced by increased catches in purse seine, gill net and trawl units. In purse seine, the average fish catch/boat varied between 4,480 kg and 3,200 kg for PFZ

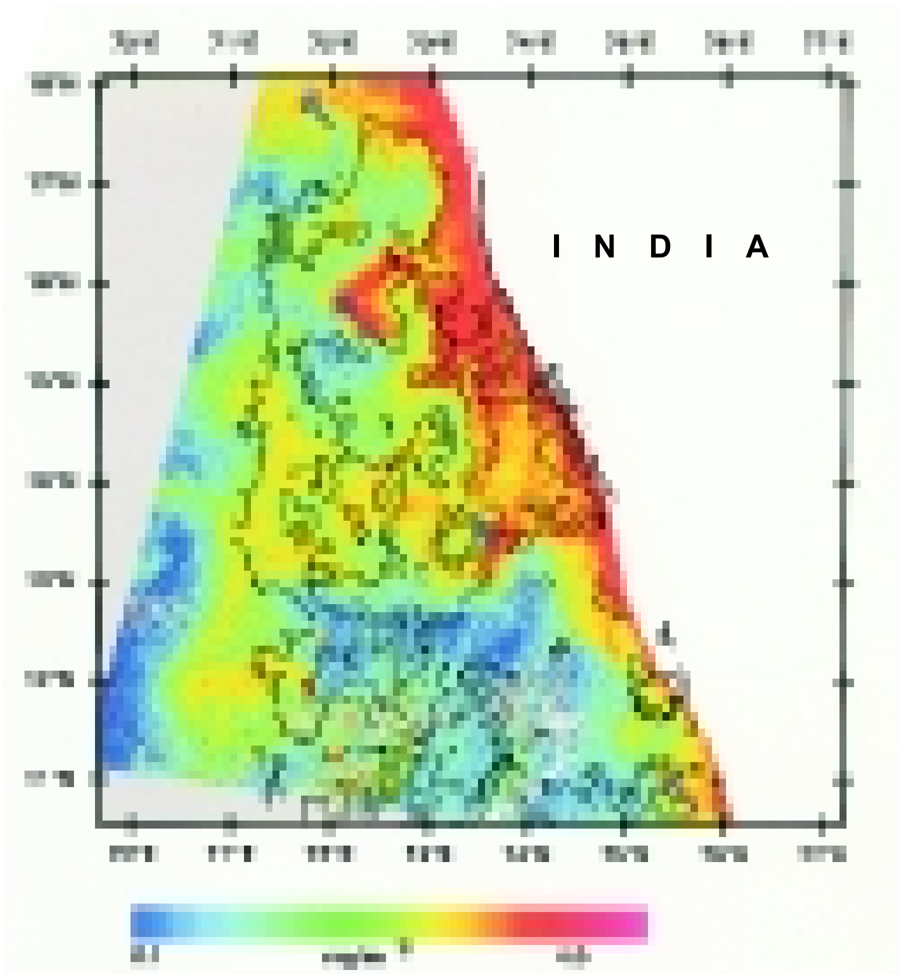

Fig. 1. Map showing the Potential Fishing Zones (PFZs) (Source: IRS P4 OCM derived Chlorophyll with NOAA SST contours)

and non-PFZ respectively off Cochin during the month of November. In the case of gill net, the same varied from 480 kg and 187 kg for the same month. In pole and line fishing for skipjack tuna around Minicoy Island the average catch/boat varied from 83 kg and 28 kg for PFZ and non-PFZ areas respectively.

4. Prospects

Apart from fishery dependent factors, fishery independent factors such as physical, chemical and biological oceanographic parameters also influence the marine fishery. Information on the physical, chemical and biological oceanographic parameters is important in predicting, locating and exploiting marine fishery resources. Recently, scientific effort has been focused upon determining the direct interactions between the fishery independent factors and individual fish stocks. Several marine fish catch predictive models have been developed in western countries using several biotic and abiotic factors. Remote sensing techniques are also found to be useful in predicting the pelagic fish catch from our coast. Field oriented time series data on physical, chemical and biological oceanographic parameters are essential perquisite for developing predictive models and the validation of remote sensing techniques. Application of GIS in marine fishery management also has been found to be promising in understanding the issues related to catch predictions and forecasting.

5. Suggested reading

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