# Our fisheries resources and the role of upwelling in their fluctuations

## Part II

## PRIMARY PRODUCTIVITY AND FISHERIES POTENTIAL

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The production of organic matter by phytoplankton initiates the whole marine food chain, which terminates in the larger fishes and marine mammals. The prime synthesisers of organic matter in the sea are the planktonic algae found in the upper layers where there is sufficient light penetration for photosynthesis. Therefore, a knowledge of the standing crop and rate of production of phytoplankton in different regions and seasons is of greatest importance. The investigations on organic production to assess the relative fertility of the sea were being carried out during the past two decades. Carbon-14 experiments on primary production have furnished valuable information on the productivity of the inshore and offshore waters of our coasts.

One of the most important factors influencing primary production is the amount of sunlight reaching the surface of the sea. A higher utilization of the incident light is possible only if the phytoplankton is concentrated in the upper layers, where light absorption by water is low. Plant growth occurs wherever photosynthesis exceeds respiration. Therefore, higher rates of production is expected in coastal waters.

### Nutrients and primary productivity

The availability of essential nutrients in the productive upper layers is one of the important factors governing the magnitude of organic production. The nutrients are brought up into the euphotic zone by the vertical mixing of the water caused by wind and wave action; processes associated with ocean currents and by upwelling of deep waters. The general level of nutrients is high in the Arabian Sea, especially so in the euphotic zone, which is a potentially productive condition. In the Arabian Sea during

monsoon, the coastal water is enriched by the nutrients brought up from subsurface levels. A direct correlation between the content of phosphates and rich phytoplankton was observed during the monsoon months. The hydrographical conditions during this period seem to be mainly responsible for the rate of replenishment of nutrients far exceeding their utilization. The process of replenishment is more intense towards the southern part of the west coast of India. During the postmonsoon the nutrient levels decreases due to theincreasing vertical stability of the waters. In the offshore regions marked variations in the nutrient levels are observed in different seasons. But in the inshore regions, the seasonal variations in nutrient concentration is relatively less because of the constant mixing of the water. On the south-west coast the maximum production of phytoplankton takes place during the south-west monsoon. There is another peak of lesser magnitude in the north-east monsoon months between December and February. Plankton production during the south-west monsoon on the west coast surpasses those from some of the most fertile coastal regions of the world. The nutrient concentrations in the Bay of Bengal is of a lower order compared to the Arabian Sea. The absence of large scale upwelling is presumably responsible for the lower level of nutrients and phytoplankton concentration here.

A direct correlation exists between primary production and nutrient concentration – low values of primary production coincided with the deficiency of nutrients. In the central part of the Arabian Sea and in the open ocean nitrates are practically absent and in the Bay of Bengal and in the Andaman Sea phosphates are almost utilised by the phytoplankton. The magnitude of primary production is influenced primarily by the availability of nutrients as other conditions are never limiting. Hence a study of the seasonal variations of nutrients could provide valuable information on the primary productivity.

**Regional and seasonal variations in primary productivity**

57 million hectares of shallow water are contiguous to the coast line of India. The continental shelf of India is much wider in certain regions on the west coast than on the east coast. There is considerable seasonal and regional variation in the magnitude of organic production. Some of the most productive regions are found on the continental slope.

The Arabian Sea is highly productive because of the presence of regions of deep water ascent. Generally the level of organic production is high near the coast and becomes less seaward. Studies on the primary production in the seas around India have shown that the shallow areas of the Gulf of Mannar, Palk Bay and Wadge Bank are extremely productive, with an average rate of 2.0 $gC/m^2/day$ during most of the year and with the highest values of over 6.0 $gC/m^2/day$. These high rates are almost equal to those found in some of the worlds most productive waters as in the regions of the Somali coast.

In the shelf waters of India, the average gross production comes to 1.19 $gC/m^2/day$, which amounts to an annual gross production of 434 $gC/m^2/day$. Assuming that 40% of this is being utilized for respiration, the net

production would amount to 260 gC/m²/year. For the zone between 50 m depth and the edge of the continental shelf, the average rate is 0.43 gC/m²/day which is moderately high. In this region the annual gross production of carbon would amount to 157 gC/m³/year and the net production 94 gC/m²/year. The net production on the western shelf has been estimated at 46 x $10^6$ tonnes per year, which is about 3 times that of the net production on the shelf regions of the east coast. Observations carried out on the west coast have clearly indicated a gradual decrease in the rate of production from shallow waters to the deeper regions of the shelf and slope. Beyond the shelf the level of organic production falls to $<0.2$ gC/m²/day. Higher rates of production are found near the Laccadive and Minicoy Islands. Certain regions of Arabian Sea is highly productive on account of the presence of unusually high levels of organic nutrients at shallow depths often within or in close proximity to the euphotic zone. When these nutrients are brought to the euphotic zone a high level of primary production could be sustained. The monsoon shift provides the required energy for the vertical mixing of the water column which brings appreciable quantities of nutrients to the surface layers. High concentration of phosphates (3.73 ug. at/l) during May-June have been observed in the eastern Arabian Sea between 0 and 200 metres. In the western Arabian Sea also high concentrations of phosphate ($>2.0$ ug. at/l) have been observed at depths of 100-500 metres. The nutrient rich water from the intermediate depths when brought up to the surface support a heavy growth of planktonic organisms which spread seaward with the surfaee currents. The migration of these organisms or the animals that feed on them can sustain large stocks of pelagic fishes in the open ocean where the apparent organic production is of a lower order. Hence large shoals of pelagic fishes could sustain in the open parts of the Arabian Sea in view of the high productivity in certain regions. Generally, the trend and magnitude of production are reflected in the fishery potential of the regions concerned.

In the Bay of Bengal, the areas of highest phytoplankton concentration were near the shore on the northern and eastern regions where there was replenishment of nutrients to a certain extent due to upwelling. The average value of 0.63 gC/m²/day found in the Bay of Bengal is moderately high. However, it is only about one half of the productivity of the west coast within 50 m depth and slightly more than the average value for the region outside the shelf. The total net production over the shelf amounts to 15 x $10^6$ tonnes. Thus it could be seen that the west coast of India with a wider continental shelf and a more pronounced upwelling accounts for three-months and the east coast one-fourth of the entire net primary production. This disparity is reflected in the magnitude of the fisheries resources along these coasts.

**Standing crop of plankton**

The Arabian Sea has been found to be the richest part of the Indian Ocean in plankton production. This goes to sustain the pelagic fisheries of oil sardine, mackerel and several others, high seas fishery and the demersal fisheries on the shelf chiefly prawns which feed on the organic matter at the bottom. The presence of upwelled waters

along the coast between Cape Comorin to Karwar is responsible for the high nutrient content of the west coast. It may be seen that the standing crop of phytoplankton is of a high order throughout, but during the south-west monsoon period it attains the peak of development. The fall in the standing crop of phytoplankton during the north-east monsoon season is partly due to the grazing effect and probably also owing to lack of some essential nutrients which act as a limiting factor.

The standing crop of zooplankton along the west coast fluctuates from 100 – over 700 ml/1000 $m^3$ over the shelf and decreases somewhat beyond. The richest area is from Quilon to Calicut, Cannanore to Karwar and Wadge Bank in the south. The peak production is in June–July and another of less intensity in October, the value fluctuating from 221-761 ml/$m^3$ over the shelf. Relatively steady but quite low volumes of plankton are noticed from December to April. For the oceanic area high value of 144 ml/1000 $m^3$ was recorded in July and there was no conspicuous secondary peak of abundance. An examination of the data relating to primary production also indicates that in almost whole of the area where standing crop of plankton is rich, organic production also is of a high order. It has been found that the abundance of surface shoals of mackerel and oil sardine during September–October 15–30 kilometres offshore coincided with the presence of a dense plankton belt from Cochin to Karwar.

In general, the standing crop of plankton is rich in certain regions and exhibits seasonal fluctuations. The standing crop of phytoplankton in the shelf is found to be of a high order during the south-west monsoon season, several times the magnitude of that during the north-east monsoon season. The zooplankton crop does not show such sharp oscillation because their peak development succeeds that of the primary producers, the phytoplankters and are probably being eaten up or carried away by the prevailing currents to distant places. All forms of life are directly or indirectly dependant on the phytoplankters, the prime synthesizers. The fluctuations in abundance of plankton is sure to effect the different levels of our harvest of fish wealth.

**Primary production in relation to fisheries resources**

The phytoplankton sustain a host of herbivores, mostly copepods, and carnivorous copepods and a host of higher forms including some fishes, and these in turn nourish the carnivores and larger forms. Therefore, a relationship which commences as a direct one gradually becomes inverse with forms at a higher trophic level.

When primary production is considered in the overall role of the food chain relation in the sea, it becomes necessary to know the efficiency of energy transfer from one step in the food chain to another. When the steps are few in the food chain higher efficiencies of food energy transfer are found. The most important direct consumers of phytoplankton are the copepods and euphausids. These crustaceans and their larvae constitute the bulk of the food of other plankton amimals including pelagic fish larvae and the plankton feeding fish. The food is converted by the fish partly into growth. The efficiency of conversion is higher in young fish and lower in old fish as the growth is slower in the

latter. It has been observed that the landings of commercial fish in intensely exploited waters is about 0.4% of the organic matter produced by the phytoplankton. The ratio of phytoplankton production to the fish landed along the coast of India is only about a half of that found in the north sea which is an intensely fished area.

Based on the data collected so far, the gross organic production on the shelf within 50 metres over an area of 1,14,520 square kilometres, where there is active fishing has been estimated at $50 \times 10^6$ tonnes and the net production available to the environment would be about $30 \times 10^6$ tonnes of carbon. The present yield of fish from the west coast is 10,32,137 tonnes which is caught mostly from this shallower inshore areas. In terms of carbon it amounts to 0.2% which is only one half of the maximum sustainable yield. For the rest of the continental shelf area, the net production amounts to $16 \times 10^6$ tonnes which would yield another 3.2 lakh tonnes even at the present rate of exploitation. So the minimum harvestable crop from the west coast seem to be around 2 million tonnes. For the east coast, taking the average production rate of 0.63 $gC/m^2/day$ the total net production over the shelf area would amount to $15 \times 10^6$ tonnes of carbon and the optimum yield of fish would be 6,00,000 tonnes. As the present yield is 3,86,521 tonnes, the potential harvest on the east coast also would be about 3 times the present yield.

Thus considering the east and west coast together the potential resources over the entire shelf region based on the yield ratio from carbon production would be at least 2–3 million tonnes of fish from both the coasts. It is therefore reasonable to think that fish landings in India could be increased to at least two fold or more by increasing fishing effort. Thus primary productivity studies apart from giving an idea of the relative fertility of water masses, enable a quantitative assessment of the potential resources and provide valuable information on the possibilities of large scale fishing.

## POTENTIAL RESOURCES

Exploratory and scientific expeditions by some research vessels in recent years have furnished valuable information on the potential marine fishery resources of the country. Investigations of the Central Marine Fisheries Research Institute, Integrated Fisheries Project, Exploratory Fisheries Project and UNDP/FAO Pelagic Fishery Project have thrown some light on the magnitude of the resources. Some aspects of the oceanographical features influencing the fluctuations in the important zonal fisheries have also been elucidated to some extent.

### Fisheries resources along the continental shelf edge and the upper continental slope

Till recently, hardly anything was known about the commercial trawling possibilities along the continental shelf edge and the upper continental slope. The research vessel Varuna and the mechanised fishing vessels Klaus Sunnana, Tuna and Velamin of the Integrated Fisheries Project have made exploratory surveys along the west coast and the south-east coast of India to locate potential fishery resources in depths beyond 50 m. These surveys indicated that potentially good fishing grounds for demersal fishes exist at different depths along the continental slope.

The investigations of the Pelagic Fishery Project have shown that in the middle of the shelf a narrow belt void of any fish recordings appears to be separating the coastal resources from a continuous dispersed distribution of mainly bottom fish on the outer part of the shelf and upper slope.

The average resources of ribbon fish along the south-west coast of India has been estimated at 67,200 tonnes whereas the highest estimate ever recorded was found in May–June 1975 (3,09,300 tonnes). The average estimate is highest along the Kerala coast (44,600 tonnes), followed by that of Southern Maharashtra (20,800 tonnes). Off the coast of Kerala the greatest abundance was from May to September with the highest estimate of 1,69,000 tonnes during July–August 1975. The average standing stock of cat fish was 84,000 tonnes whereas the highest in 1975 was during June/July (3,98,900 tonnes). The highest estimated average biomass of cat fish is along the coast of Kerala (43,790 tonnes), followed by Karnataka and Goa (26,670 tonnes). Along the Kerala coast, the period of abundance is during the second and third quarters of the year in the depth zone 50–80 but cat fish landings in the region were high during the third and fourth quarter. This anomalous situation is mainly due to the fact that the traditional fishery cannot effectively exploit the resources during the monsoon months when the stocks are highest in the area.

Good catches of deep sea lobster *Puerulus sewelli* and deep sea prawns *Panaeopsis rectacuta, Aristeus semidentatus* etc along the upper continental slope off Quilon have been obtained. The resources of kalava along the south west coast from Ponnani to Quilon is immense and awaits exploitation. These facts indicate the availability of good potential resources along the continental slope.

**Conventional demersal fishery resources**

The depths upto 50 metres are being fished intensively by country crafts and small mechanised boats along certain stretches of the coast. There has been a concerted effort on the part of those using mechanised boats for almost exclusively trawling for prawns. This results in a shift in gear and effort exclusively towards prawn fisheries and hence some other inshore fisheries have remained underexploited or unexploited. A wider shelf on the west coast invariably supports a greater abundance of demersal fishery resources. In the shelf waters beyond 50 metres there are considerable resources which remain virtually untapped. In the depth zone 75–100 m the thread fin bream, *Nemipterus japonicus* predominated in exploratory and experimental fishing operations, sometimes forming 75% of the trawl catch. Although the narrowness of the shelf has an adverse effect on the supply of demersal fishes on the east coast, *N. japonicus* resource along the east coast is also high. Sufficient fishing has not been made along this coast in the depth zone in which this species is predominant to obtain a clear picture of the resources. There is every reason to be optimistic and with diversification of fishing to exploit all types of demersal fishery resources, the fish catch rates and production should go up considerably.

**Conventional pelagic fishery resources**

The exploitation of the pelagic shoals is carried out by non-mechanised fishing craft when the shoals move close to the shore. The UNDP/FAO Pelagic Fishery Project has confirmed the earlier findings that along the west coast in depths upto 40 metre there exists a diversity of species predominantly constituted by the oil sardine, mackerel, whitebait, carangids, horse mackerel, silver bellies, lesser sardines etc. The average magnitude of the above resources in the project area has been estimated to be around 2 million tonnes,

Upto 15 metres depth there is a continuous belt of shallow water mix composed of carangids, lesser sardines, silver bellies, butter fish etc. In the Project area the resources of shallow water mix in 1975 have been found to vary between 25,000 and 1,84,000 tonnes with an average of 90,000 tonnes. At the height of the upwelling they probably move shoreward and live pelagically. The shallow water mix stocks are of sufficient magnitude to support commercial fishery using small mechanised boats with pelagic trawl. The resources of whitebait found slightly away from the coast was estimated at over half a million tonnes in June/July, while the average was 0.34 million tonnes. They undertake regular annual migration, moving southward with the onset of the monsoon and concentrating in dense shoals east of Cape Comorin in July–August. Preliminary work has shown that whitebait is easily amenable to fishing with small and medium sized mechanised vessels.

One of the resources of considerable magnitude in the Project area is that of horse mackerel comprising mainly of true horse mackerel (*Megalaspis* sp., scads (*Decapterus*) and trevallies (*Caranx* spp.). In the Project area alone, the average standing stock of horse mackerel estimated through stock assessment surveys is of the magnitude of 1,40,500 tonnes which is considerably higher than the present all India yield. The highest estimate in 1973, 1974 and 1975 were 1,69,300, 2,29,300 and 5,52,800 tonnes respectively. It was observed that the average stock is the highest along the Kerala coast (70,260 tonnes), followed by that of Sourhern Tamilnadu (56,240 tonnes). They are found in good concentrations on the middle and outer shelf extending from 30 to 100 m bottom depth, but in certain seasons and areas their distribution extends shorewards upto 15–20 m depth. The highest abundance of the horse mackerel resources off Southern Maharashtra occurs during the first and second quarters, along the coast of Goa and Karnataka it is during the second and fourth quarters and off Kerala and Southern Tamil Nadu coasts it is during the second and third quarters of the year.

There are good pelagic fishery resources supported chiefly by mackerel and sardine. The recent investigations by aerial and acoustic surveys conducted by the Pelagic Fishery Project have confirmed that both oil sardine and maekerel shoals occur between 30–45 kilometres from the shore when they are not available in coastal waters. Generally, sardine schools are located closer to the shore than those of mackerel. For both oil sardine and mackerel the area between 10°-14° was particularly rich with 82% and 94% respectively of the total number of schools located in the whole area. The magnitude of the sardine resources at

the time of aerial survey in 1974 and 1975 were 5,00,000 tonnes and 3,00,000 tonnes respectively. During September-October 1975 the total biomass of mackerel was found to be of the order of about 7,00,000 tonnes whereas, it was only about 1,00,000 tonnes in 1974. The project data indicate that the proportion of large adult mackerel and oil sardine is significantly greater in the offshore purse seine catches than in the catches from inshore areas. Medium sized vessels with purse seines may well prove to be both efficient and economic units for fishing of oil sardine and mackerel, since the distance from the shore to the fishing grounds will be short and the weather conditions from the middle of August onwards are generally quite fair. The present traditional fisheries for both species are mainly exploiting the O-group when these enter the near shore waters. Older and larger fish are apparently occuring rather irregularly so as to come within the reach of the present traditional fisheries and they are therefore exploited only quite sporadically.

Both mackerel and oil sardine have a rather restricted longevity, reaching sexual maturity at the end of first year of life. The fishing mortality is significant mainly during a short fishing season in the first year of life. Therefore a high rate of natural mortality could be expected. Therefore, the present fishery may be well below the level of exploitation required to produce the maximum sustainable yield.

**Non conventional fishery resources**

Till recently, cuttle fishes obtained in the regular trawling operations were the first items to be thrown out as there was only little demand for these. Commercially important species of squids such as *Symplectoteuthis ovaleniensis* occur along the west coast of India. There are good concentrations of *Loligo* species along the west coast of India. Large concentrations of myctophids occur along the west coast especially near the Angria Banks and off Bombay shelf waters. This resource is very important in view of their high vitamin A content as well as the oil content (110 litres per ton). Apart from the bathypelagic scattered schools and / or diffuse layers just off the edge, very few pelagic fishes have been observed beyond the middle part of the continental shelf. So far the project has not produced evidence of any substantial commercial resources of pelagic fish beyond the continental shelf. Along the continental shelf edge of the south-west coast as well as the east and north west coat of India, large quantities of the swimming crab, *Charybdis edwardsi* form a dominant constituent of the demersal fishery resources. They abound in depth zone 101-180 m. Any overall programme at the exploitation and utilization of resources which are at present not properly exploited or still remains unexploited should considerably help in the diversification of fishing leading to a more balanced development of fishing industry.

Our pelagic as well as demersal resources show large scale seasonal, annual and regional fluctuations. These fluctuations in the total resources is evidently related to the special environmental conditions prevailing. The planned exploration and judicious exploitation of the resources and their utilization are needed for the integrated development of the marine fishery resources.

# Prawn Fishery of Chilka Lake: Its Contribution to the Export Trade of Marine Products of Orissa

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The importance of marine prawn resources of India has been established from the increasing foreign exchange earnings by export of prawns and prawn products. Prawn, as single largest quantity of marine products, shares 77.2 and 90.0 percent in quantity and value respectively in the total export of marine products from the country (Annon. 1974).

## Export of Marine Products from Orissa

Export trade of marine products from Orissa, though a very recent development, is gaining much importance and contributes substaintially to the export promotion of the State. Marine products from Orissa, at present, includes only frozen prawns. The trade has registered a steady increase since 1968–69 and the present volume of trade accounts for about 2.20% of the country's total export of frozen prawns. Most of the processing plants in the State are, at present, located in Puri, Paradeep and around Chilka lake. The promising future of marine products export trade in the State can be seen from the trend given in Table 1.

TABLE 1

*Export of marine products from Orissa*

| Year | Frozen Prawn | Other products | Total |
|---|---|---|---|
| 1968–69 | | | |
| Q: | 3,137 – | Q: | 3,137 |
| V: | 94,110 – | V: | 94,110 |
| 1969–70 | | | |
| Q: | 4,180 – | Q: | 4,180 |
| V: | N.A. – | V: | N.A. |
| 1970–71 | | | |
| Q: | 61,560 – | Q: | 61,560 |
| V: | N.A. – | V: | N.A. |
| 1971–72 | | | |
| Q: | 179,079 – | Q: | 179,079 |
| V: | 50,72,000 – | V: | 50,72,000 |
| 1972–73 | | | |
| Q: | 371,116 Q: 4395 (FL) | Q: | 375,511 |
| V: | 93,70,428 V: 82,470 | V: | 94,52,898 |
| 1973–74 | | | |
| Q: | 375,042 Q: 16,766(FL) | Q: | 391,808 |
| V: | 11,193,036 V: 434,007 | V: | 11,627,043 |
| 1974–75 | | | |
| Q: | 823,851 - | Q: | 823,851 |
| V: | 24,150,505 – | V: | 24,150,505 |
| 1975–76 | | | |
| Q: | 1063,790 – | Q: | 1063,790 |
| V: | 44,982,000 – | V: | 44,982,000 |

Q: Quantity in Kg. N. A. Not Available
V: Value in rupees FL Frozen Frog Legs

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