Our fisheries resources and the role of upwelling in their fluctuations

Part III

THE ROLE OF UPWELLING ON FLUCTUATIONS

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The abundance and distribution of fish in any region are influenced to a great extent by a number of environmental conditions. The most important among these are the physical features of the land bordering the ocean, fluctuations in temperature, current, intensity of light, salinity and oxygen saturation, upwelling and availability of food in the environment. Fluctuations in the abundance of phytoplankters which are the prime synthesizers surely affect the different levels of the resources. The phytoplankters are dependant on the nutrients like phosphates, nitrates, silicates and trace elements in the water for growth and multiplication. The nutrient contents in turn, is dependant on the vertical mixing up of the water which bring the nutrients to the euphotic zone. The movement of water masses is influenced by the salinity and temperature gradients and meteorological factors like wind force. Therefore, any change in any one of the above factors in a region ultimately affects the fisheries resources. To have a thorough knowledge of the resources of the seas, a study of the above factors is inevitable. In recent years very useful information on the movement of the coastal water masses, the relation of the monsoon winds determining the coastal current, the upwelling along the coast, the annual phosphate cycle etc. have been collected. These have helped in understanding the reasons for the high productivity and also to some extent the factors determining the fluctuations in the important fisheries along the west coast of India.

General Conditions of Coastal waters

The south-west (May to September) and north-east (November to March) monsoon winds prevail in the northern Indian

Ocean. It is well known that the surface currents in the Arabian Sea and the Bay of Bengal is much influenced by the winds associated with the summer and winter monsoons. The circulation in the open ocean generally conforms to the wind pattern but the movements near the coast are mainly influenced by the configuration of the coast line. From about February a south-west flowing surface current comes into being in the Arabian Sea and the Bay of Bengal and it strengthens during the south-west monsoon period. The rain water which enters the Arabian Sea during the south-west monsoon is carried southwards by this coastal current. This water mass is later on carried northwards to the Bay of Bengal on touching the coasts of Ceylon. The direction of the current reverses after October and during the north-east monsoon a north-westerly current from November to about the beggining of January prevails. However, in the oceanic region in the south, the circulation remains almost the same as during the south-west monsoon. During the above period, the easterly flowing monsoon current is absent and the westerly flowing north equatorial current is formed when the winds are from the north-west.

Very wide fluctuations in the surface temperature are observed in the Arabian Sea (21°C to 30°C). During January the entire western shelf is covered with homogeneous warm surface waters, except the southern part of the Wadge Bank with waters of comparatively low temperatures and oxygen contents. Generally, the surface waters along the coast are comparatively colder than the offshore waters during the premonsoon (March to May) and post monsoon (September to November) while they are warmer during the winter (December to January). Off the west coast of India, even though the general pattern of the discontinuity layer (thermocline) shows a definite seasonal trend, it fluctuates a great deal. Above the thermocline the temperature decreases and the salinity increases from south to north. Below the thermocline both these parameters decreases towards the north. The thermocline is deepest during winter months (from 120 to 80 m). In May-June the thermocline was very sharp and had moved upward all along the coast. It was intensified during June and reached the surface by July-August. During the post monsoon period, the thickness of the upper mixed layer gradually increases.

The pattern of oxygen concentration in the Arabian Sea is in general agreement with that of temperature. Usually the oxygen content of the surface waters is near saturation and it decreases with increasing depth to a minimum at intermediate depths. Consumption of oxygen close to the bottom is more as the bottom sediments contain much organic matter. This is commonly encountered in shallow shelves, where upwelling normally occurs. Dissolved oxygen content is generally low below 20 m depth during the monsoon and it shows a gradual increase by the post monsoon season.

What is upwelling

Vertical mixing up of the water are of common occurrence in oceans. Upwelling which is of particular importance, especially to life in the sea is an ascending motion.

By this, cold, nutrient rich water from depths usually not exceeding a few hundred metres is brought into the surface layer and is removed from there by horizontal flow caused by prevailing winds. Upwelling and sinking of oceanic waters occur mainly in areas of convergence and divergence at the sea surface. Mostly these divergences and convergences are caused by the wind stress exerted by the prevailing wind on the sea surface. A secondary reason for the upwelling may be the nature of the local topography of the coast and the continental shelf in relation to ocean currents. Bottom water may also come up if submerged land mass or ridges obstruct the course of bottom currents. The intensity and duration of upwelling in any region vary depending on the velocity of wind and its sustained duration. A change in these factors will change the area of upwelling and will have great impact on the resources of the sea.

Regions of upwelling

The most intense upwelling occurs along the western coasts of continents in the middle latitudes. In these regions a one-sided divergence of the surface layer is induced by wind stress parallel to the coast line and at the boundaries of currents. Associated with the Peru Current system in the Eastern Pacific very intense upwelling occur in winter. This narrow belt of cold, upwelled water makes the coastal regions of Peru the richest fishing grounds in the world. Northerly and north westerly winds cause upwelling in the region of the California Current and the most intense upwelling shifts northward along the coast progressively in spring and summer. Intense upwelling is observed in the Benguela current region in summer and fall. Along the north-west coast of Africa upwelling in spring and summer is associated with the Canary Current. Upwelling has been observed along the South Arabian coast during the south-west monsoon. Another upwelling region is the vicinity of Somali Current area. Here, the current flows during the south-west monsoon from the southern hemisphere along the east coast of Africa into the southern part of the Arabian Sea. Upwelling occurs along the coast of Java and Sumbava during the south-east monsoon, from May to September.

The oceanographic data collected by the Pelagic Fishery Project in recent years have elucidated the seasonal pattern of the main environmental parameters along the south-west coast of India. All along the west coast from Karwar southwards, upwelling of cold oxygen low water into the coastal shelf begins in February and lasts till August/September. Sinking takes place from October to about February. The maximum intensity of upwelling is north of Calicut and it lasted longer in the northern part of the Project area than in the south. Even though upwelling shows a seasonal trend along the west coast, it may vary considerably from year to year. Upwelling of limited extent and duration has been observed off Bombay in the beginning of the north-east monsoon. In Minicoy region, upwelling is of common occurrence during November-December. Upwelling leading to the enrichment of water to a certain extent reportedly occur in the Bay of

Bengal from Madras to the Hooghly river from January to June at different centres. The intensity and duration of upwelling in the Bay of Bengal is not as pronounced as along the west coast of India.

Effects of upwelling

The cold nutrient rich water, often deficient in oxygen which is brought up to the surface layers by upwelling influences not only the weather conditions but also all forms of life in the water. It brings about horizontal anomalies in the physical and chemical properties of the water that normally have marked vertical gradients.

Marked changes in the climate along the western coasts of continents are brought about by upwelling. As the eastern boundary currents flow from higher latitudes along these coasts upwelling lowers the temperature. The influx of cold upwelled water cools the air and increases the relative humidity. Therefore, thick mist or fog is also sometimes found along the coasts during the upwelling associated with the south-west monsoon. Diurnal sea breeze, which is particularly common along coasts affected by upwelling is also partly caused by upwelling. Differential heating of the sea and land brings about a pressure gradient from the sea to land causing inshore winds which bring cool moist air into the land.

The vertical sections of temperature in an upwelling region show the shallow isotherms ascending steeply. On the west coast, with the onset of upwelling, the thermocline rises steeply near the coast and may even intersect the surface in July. Thus, the vertical temperature gradient is decreased inshore. In August, the winds strengthen and are south-westerly to westerly. The surface flow during this period is almost parallel to the coast owing to the boundary conditions. This together with inflow of fresh water from land owing to heavy rains stratifies the surface layers which is very unfavourable for upwelling. Hence upwelling practically stops from the beginning of October. Relatively large horizontal gradients in the surface temperature are encountered in upwelling regions. For example, in July and August, the months of most intense upwelling along the west coast, the coastal surface water is about 4°C cooler than the water at the seaward side of the shelf. In winter (December to about February) this difference is seldom 1°C. Generally, the range of temperature down the shelf has been found to be less than the temperature difference between the surface and the bottom waters in the offshore regions during premonsoon and monsoon (June to August) seasons. Conditions are just the opposite during the rest of the year.

The oxygen minimum layer is most pronounced in the Arabian Sea. Normally, this oxygen minimum layer is at a depth of 100 to 150 m. There is practically no oxygen below this layer in the Arabian Sea. This permanent oxygen minimum layer is a layer of minimum consumption and of minimum replenishment. The oxygen deficiency of this water is due to its consumption during oxidation of the rich organic dead matter close to the bottom. The enrichment of the bottom waters itself is the result of death and decay of organisms

which had sunk elsewhere and transported to other regions by bottom currents. During upwelling, subsurface water of relatively low oxygen content ascends to the surface layers having sufficient amount of sunlight. The surface layers are aerated by the action of winds and waves. As the oxygen minimum layer is very rich in essential nutrients high organic production occurs in the upwelling layers. The oxygen production by the high phytoplankton standing crop results in the addition of more oxygen in the lighted zone. This causes the development of zooplankton at the edges of this zone and naturally, pelagic fish migrate into the area for feeding. At times, the upwelling may be suddenly intensified or the oxygen replenishment apparently slowed down due to slow circulation caused by changes in the direction and velocity of the winds. Death and decay of large quantity of organic matter enriches the nutrients further and depletes oxygen in the subsurface layers. The oxygen minimum layer is thereby brought close to the surface and mass mortality of fish and other marine animals may result. This phenomenon is commonly encountered in areas of offshore upwelling in divergence zones or in centres of cyclonic eddies.

Phosphate is one of the principal nutrients essential to all forms of life in the sea. Phosphate and dissolved organic phosphorus, generally increases with depth. Low values are found at the surface and maximum value at some intermediate depths. In the process of upwelling, nutrient salts brought up from the subsurface layers enriches the euphotic zone. Concentration of essential nutrients like phosphates, nitrates, nitrites and silicates have been found to be generally high in the upwelling regions of the west coast and east coast of India. Surface salinity is usually decreased by upwelling. Low salinity and temperature are useful indicators of upwelling.

Upwelling has important effects on the ecology and distribution of marine organisms in the regions concerned. Upwelling results in a fall in temperature to optimum levels (from 30–31°C to 22–25°C), a slight lowering of salinity (from 35–36‰) and an abundance of nutrients. These lead to the growth and multiplication of phytoplankters. The unicellular microscopic plants are distributed in the euphotic zone. The phytoplankters are thus able to sustain a host of herbivores, mostly copepods and some higher forms including small fishes. These in turn nourish the larger forms of life. The food relationship which began as a direct one gradually becomes inverse with forms at a higher trophic level. Extreme coldness of water may temporarily effect the phytoplankton production in an upwelling region. Sometime will elapse for the growth and multiplication of phytoplankton and for transformation into zooplankton, and still more time will elapse for the zooplankton to be consumed by the primary carnivores. During this period the organisms involved may be transported away by currents and waves from the site of upwelling and initial high productivity. Therefore, the region of high productivity of marine animals depends to a great extent on the direction and force of currents. Usually, the herbivores

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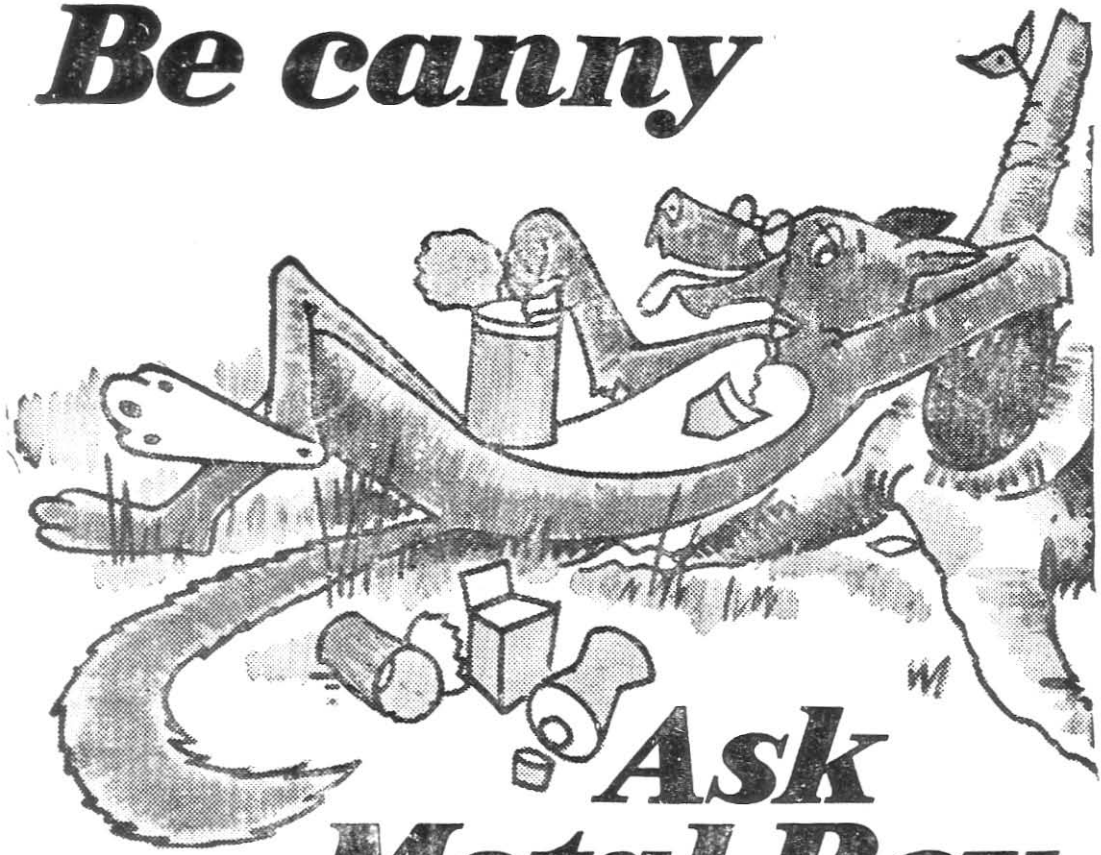

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are found near the zone of upwelling where phytoplankters are produced in abundance and other higher groups occur mainly farther away from this zone.

High nutrient content off the west coast of India is mainly due to the presence of upwelled waters from Cape Comorin to Karwar. The standing stock of plankton shows seasonal fluctuations. During the period of upwelling the standing stock of phytoplankton was highest in the inshore regions and the highest standing stocks of primary carnivores were found when the upwelling began to subside. Generally, the standing crop of phytoplankton is of a very high order all along the west coast but during the south-west monsoon period it attains the peak of development. At this time it is several times the magnitude of that existing during the north-east monsoon season. In August–September nearly all along the coast from Quilon to Ratnagiri a fairly dense belt of plankton is present, generally about 156 kilometres from the shore. Thereafter, the distribution of plankton became rather patchy. January and February was a period of low abundance. From March onwards plankton densities increased gradually with the concentrations a little off the coast reaching the peack in August/September. The zooplankton populations do not show such wide fluctuations as their peak development succeeds that of the primary carnivores, the phytoplankters and are eaten up by higher forms.

Fluctuations in fisheries resources

When the oxygen minimum layer begins to rise along the coast due to upwelling, fish populations migrate into shallow water or rise into the surface layer. Concentration of demersal fish is generally high at the seaward boundary of this zone. This boundary fluctuates with the intensity of upwelling. Seaward of the upwelling area in the surface, high organic production is observed. Pelagic fish move further offshore and feed on zooplankton which had developed during upwelling. The movements of the fish could be related to the water movements and availability of plankton. The fishes congregate in various areas along their routes of migration, when the feeding conditions are favourable. Thus, it is evident that fish catches generally coincide with concentration.

Normally, the fish will tend to remain in their particular water mass. Nevertheless, movement from one area to another may take place as a result of changing behaviour requirements. Water movement is responsible to a great extent for the changes in the vertical and horizontal distribution of sardine and mackerel, two of our important pelagic fishes. It is presumed that at the onset of upwelling, migration of mature sardine and mackerel to spawning areas not accessible to the fishing fleet take place. Due to the phenomenon of upwelling in this part of the coast, most of the pelagic fish concentrate in the surface waters during August–September. Good concentrations of oil sardine and mackerel surface schools occur just after the period of the south-west monsoon until about mid-October, extending in a narrow belt along the coast, usually between 15 and 30 kilometres offshore, 200 kilometres from Calicut north-

wards. These aggregations are evidently related to the favourable environmental conditions during that period resulting from the upwelling on to the continental shelf of cold, oxygen low waters and to the abundance of plankton. Surface schools of oil sardine, mackerel, horse mackerel, scad, anchovies and tuna concentrate on the surface waters of the mid-shelf to feed on the abundant plankton during the third quarter of the year. The stratified hydrographic condition along the coast almost disappears in October/November and is replaced by isothermal conditions. Then the plankton diminishes, and these fish disperse and probably move inshore where they become available in good quantities to the traditional shore fisheries.

Mackerel consumes large quantities of pnytoplankton and some zooplankton. Therefore, areas with high phytoplankton productivity is favourable for the abundance of mackerel. The shoreward movement of mackerel is influenced to a great extent by the abundance of planktonic food. However, during the south-west monsoon period demersal fisheries are poor and pelagic fishes like oil sardine and mackerel also move away from the normal coastal fishing zones. Sudden decrease in the temperature which amounts to 6 to 7°C, and the oxygen poor upwelled water and very low salinity are the probable causes for this. The dominant food of oil sardine is zooplankton. The high abundance of oil sardine during the north-east monsoon months is on account of the high production of plankton during south-west monsoon months. The oil sardine fishery appears to dominate in the region between Alleppey and Malpe and the mackerel fishery from Calicut to Malwan. Thus, the northern regions appear more favourable for the mackerel fishery. This may primarily be due to a change in the hydrographic conditions, especially an increase in salinity occuring northwards from the region off Kasargod. Mackerel and sardine become increasingly abundant from Quilon northwards from September. Abundance of both fisheries is found during December-January in the northern regions when the northward movement of water along the coast is prevalent. December appears to be the peak season for oil sardine and October for mackerel.

The whitebait generally undertake regular seasonal migration. They concentrate in the south off Kanyakumari District during the period of upwelling, and move to the south-west coast from October onwards. North of Quilon the whitebait are usually found between 10 to 30 kilometres offshore. However, in the south, they are frequently found quite close to the shore. A direct relation between plankton concentrations off Karwar, Calicut and Cochin and dense concentrations of white bait

was noticed in recent years. During June-July period the high concentration of white bait near Cape Comorin coincided with the high plankton values observed in the area. The resources of shallow water mix like *Caranx kalla, Kowala coval, Lactarius,* Leiognathids and Sciaenids are generally confined to waters of less than 15 m depth. However, at the time of intensive upwelling, they probably move away from the inshore areas and live pelagically.

The abundance of prawns is also dependant to a large extent upon the hydrographical conditions along the coast. The fluctuations in the availability of prawns have been found to be in general agreement with the changes in the depth of the thermocline. Prawns congregate in areas where the depth of the thermocline is less. The prawn fishery is predominant off the Kerala coast particularly off Calicut and Quilon. The prawn catch has been generally higher when cooler denser waters prevail along the west coast. Ideal conditions for the abundance of prawns exist along the continental shelf during the monsoon period. The formation of mud banks in the above regions also contributes to the flourishing prawn fishery.

Submarine banks hinder the even flow of the currents. This causes eddies leading to rapid sinking of plankton. Most of the demersal fishes have a food chain with the sinking matter as a first link. Therefore, banks and surroundings of submarine elevations like the Wadge Bank and the Quilon Bank which are close to our coasts sustain good demersal fishery resources.

From the foregoing, it is evident that concentrations of fish are evidently influenced by the plankton distribution and abundance associated with upwelling. The knowledge of the seasonal vertical as well as shoreward and seaward migrations of demersal and pelagic fishes is important in fishery management. They explain the possibilities of exploitable resources. The seasonal migrations result in changes in the availability of fish and in the composition of the catches. Prediction of abundance and distribution of commercially important fishes has been thought of for long as it is an imperative need for planned exploitation. However, it has been rather difficult to attain this objective. Accurate prediction of abundance and distribution of various fishes depend on the knowledge of both physical and chemical characteristics of the ocean as well as the life history, physiology and behaviour of the different species. The main object of the Pelagic Fishery Project is to assist in the development of Pelagic fisheries on the south-west coast through resources surveys. This involves the assessment of abundance of the stocks of sardines and mackerel and other pelagic fishes and their seasonal fluctions in the distribution in relation to the environmental conditions. It is expected that we can gain considerable knowledge about the availability of fish during different seasons and the fishing industry in India may prosper and that it will have great impact in enhancing our national economy. ●

NEWS AND NOTES

New Chairman of MPEDA

Mr. S. Gopalan I. A. S., Special secretary to the Chief Minister of Kerala has been appointed Chairman of the Marine Products Export Development Authority. He took over charge from Mr. S. G. Sundaram I.A.S., Chairman of the Cardamom Board, who was also Chairman of MPEDA, on 16th March in the presence of Mr. C. Cherian, President of the Seafood Exporters Association of India and Officers of the MPEDA and SEAI.

Central Advisory Council on Trade

The Board of Trade and the Advisory Council on Trade have been merged by the Government of India to form a new body, the Central Advisory Council on Trade. Consisting of 29 members, the council has as its Chairman, the Minister of Commerce, while the State Minister of Commerce will be its Vice-Chairman.

Mr. C. Cherian, President of the Seafood Exporters Association of India who was a member on the Board of Trade, is nominated to the newly constituted body.