FISHERIES OCEANOGRAPHY IN INDIA

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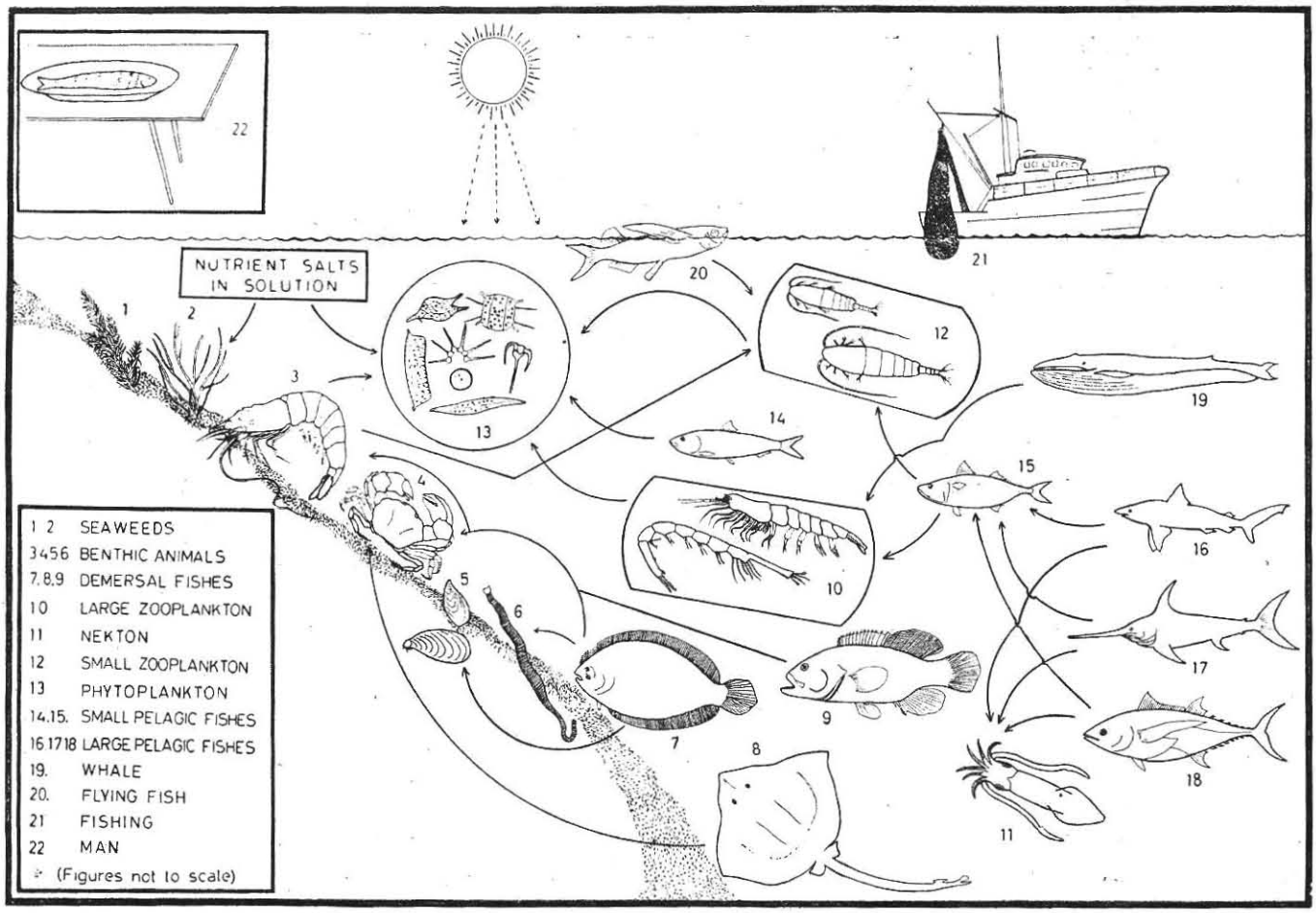
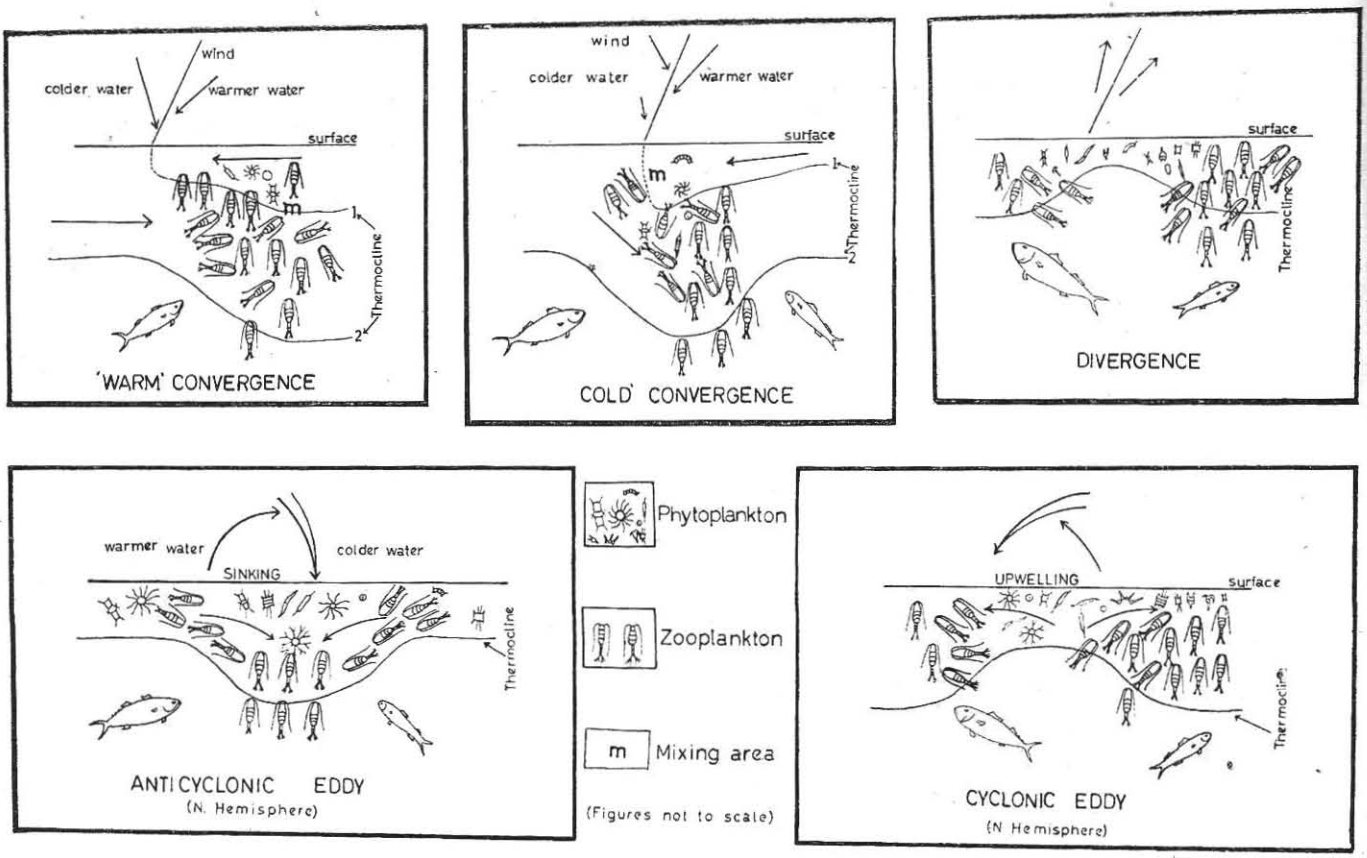
THE term 'fishery' is not meant to refer to fishes exclusively. It comprises forms such as the enormous whales which are really mammals, on the one hand, to fishes proper and to such forms as prawns, crabs, lobsters, shrimps, turtles, oysters, clams, and so on. Species which swim about freely and migrate from place to place, such as the tunas, sardines, mackerels, etc. constitute pelagic fisheries; those which are confined to the sea bottom mostly, flat fishes, perches, rays, prawns, lobsters, etc. constitute the demersal fisheries.

The harvest from the sea in terms of the above fisheries all over the world in 1966 was over 56,000,000 tonnes. In India, our average marine landings amount to 800,000 tonnes of which 80 per cent occur on the west coast. The source of all these resources in the oceans, the factors governing them, assessment of the resources and the rational exploitation of them in an economic manner constitute 'fisheries oceanography'.

The study of the oceans is one of the most composite of sciences, involving many branches of knowledge. The study of the ocean currents, the tides, the temperature of water, saltiness (salinity) of the water, the dissolved nutrients in the water, such as phosphates, nitrates, silicates, etc., the dissolved gases such as oxygen and

Food chain





Convergence zones where the eddies occur and the plankters accumulate

carbon dioxide, is approached through physics and chemistry. The charting of the ocean margins and the mapping of the relief of the ocean beds are matters for physical geographers. Intimately bound up with the great ocean currents and tides are meteorological and astronomical phenomena. These studies have also a bearing on navigation and often the term hydrography is employed for them. Study of the crust of the ocean floor deposits of minerals, etc., constitutes geology. Then, there is the study of the life in the sea, marine biology, which involves plant life and animal life, their abundance and the factors affecting them and many other problems in relation to the environment. To these must be added the application to the fishery industry of all knowledge of life and conditions of life in the sea, fishery research. A knowledge of statistics is invaluable in the interpretation of the results of research. Thus, fisheries oceanography is the study of the fisheries with reference to their oceanic environment; it seeks to develop fisheries forecasts and predictions and other practical services for fishing operations.

Study of the Ocean

The study of the ocean is beset with difficulties that do not arise in the study of terrestrial plants and animals. A severe handicap is the impossibility of watching most inhabitants of the sea in their natural habitats. For deeper waters, the biologist is forced to rely almost entirely on trawls, dredges, grabs, bottom samplers, different types of nets and other gear for obtaining the animals and plants he wishes to study. Specially fabricated bottles are used for sampling water for analyses. In recent years, under-water photography, television and electronic devices have come to the aid of seekers of knowledge of the denizens of the deep. For operating these variety of equipments, it will be obvious that cruises have to be undertaken and, for this, a suitable boat, a *research vessel*, is essential. As it will not be possible to tackle all the material collected on such cruises and continuity of observations were found necessary, shore-based laboratories came to be established. Many such laboratories having research vessels of their own function in most of the advanced countries. In India, the Central Marine Fisheries Research Institute is the foremost in south-east Asia engaged in marine work since 1947.

Population of the Sea

Let us now briefly consider what these studies have revealed and seek to achieve. The organisms mentioned earlier as contributing to the fisheries are but an insignificant fraction of the population of the sea. The sea is populated with myriads of animals and plants of various kinds and sizes—from single-celled minute forms that could be seen only under very high magnifications of a microscope, to such giants as the whales among the

animals and the seaweeds, kelps, among the plants. Among the latter, almost all the visible ones are attached to rocks or boulders on the shore or near the shore and confined to a narrow zone.

The easily discernible animal populations—fishes, whales, squids and so on—are able to make their way through the waters, sometimes hindered, sometimes helped, but rarely or never carried away against their will by the currents of the sea. Some swim faster than the currents in the ocean and are able to make headway against them. A few others are able to move against weak currents, such as shrimps, prawns, krills, and jellyfishes when pulsating strongly; but many less evolved creatures are generally at the mercy of the wind and waves and are carried wherever the waters are flowing. These are the drifting life of plants and animals, some visible as specks and others only under a microscope, technically known as plankton or plankters, as opposed to the swimmers mentioned earlier, the nekton.

These micro-organisms, though individually insignificant, occur in such large quantities—a drop of water at times holds millions of the plants or some thousands of the animals—that collectively, they surpass all other life in the water in bulk.

Just as the green plants containing the vital chlorophyll synthesise (photosynthesis) all organic matter on land, in the waters also, the same process takes place; only the plants concerned here are simple single-celled forms occurring in billions, the prime synthesizers of all food in the vast masses of water on which all other life directly or indirectly depends. These minute plants are collectively known as phytoplankters and the corresponding animals as zooplankters.

Phytoplankters are highly nutritious. They contain carbohydrates, proteins, fats, oils, etc., synthesized by them. As an example, it may be mentioned that the value of cod liver and other liver oils, their vitamin content and so on, have been traced through the fish's diet ultimately to synthesis of these by the phytoplankters.

There are hundreds of species of phytoplankters and zooplankters in the water, some characteristic of certain waters or regions; the latter species enable one to use them as indicators of certain water qualities. We have freshwater and marine species, species of the Arctic, temperate and tropical regions. Around our shores over 2000 species occur of which only some are seen at a time and further, only a few of these really contribute to the bulk.

Organic Production and Periodicity

Each of the species of phytoplankton has its period of growth and growth rate depends on many external factors such as temperature of the water, salinity, nutrients available (phosphates, nitrates, silicates, trace elements and so on, as for land plants), and the physiological state of the species itself. The external factors are governed by the water movements, horizontal (ocean currents) and vertical (upwelling, bottom water coming to the surface) and these in their turn are influenced by seasonal and climatic factors. As photosynthesis is possible only in the presence of sunlight, the plant life is confined to the top layers where light penetrates. These factors bring about a periodicity in the production of phytoplankters.

In India, on the west coast, maximum production of phytoplankton takes place during the south-west monsoon months of May to September, after which there is a decline in the crop; later, during the north-east monsoon also, another peak of production takes place—maybe any time between December and February—though of a lesser magnitude compared with the first.* On the west coast of India, the magnitude of production is of a very high order surpassing those known from some of the most fertile waters of the world.

On the east coast of India also, generally, the maximum organic production occurs during the S.W. monsoon months, followed by one or more peaks of production of a lesser magnitude during the succeeding monsoon. However, the magnitude of production on the east coast waters is only about a fourth of that on the west coast. This is reflected in the marine fish production also.

The results of the International Indian Ocean Expedition so far published indicate similar very high organic production and periodicity in the Equatorial region, Andaman Sea, waters of Malay Archipelago, Somali and Arabian coasts.

Factors for Production

Researches have shown that it is during the S.W. monsoon months that conditions in the waters attain the optimum for growth of phytoplankters; abundance of nutrients due to upwelling of sub-surface (where they are regenerated by bacterial action on dead sinking organic matter) water to the upper layers, the euphotic zone, and river discharges; a fall in the temperature of the water, from 31-32° C to 23-25° C due to cold upwelled water; and a fall in the salinity of the water from 35 parts per thousand to 30-21, to mention a few important ones. At no time is there a complete depletion of the nutrients to act as a limiting factor; however, the physiological state of the phytoplankters themselves, a slow down of their multiplication after a strenuous period of growth earlier, appears to act as a limiting factor.

The ideal conditions for growth narrated above are brought about by the action of winds, currents and rotation of earth which during the period concerned bring about displacement of surface water away from the

* R. Subrahmanyan, *Proceedings of the Indian Academy of Sciences*, Vol. 50, pp. 113-253

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coastal regions leading to the upwelling of bottom waters. This phenomenon is spread over a vast area—along the west coast of India, Somali and Arabian coasts, some places in the Bay of Bengal, the Equatorial waters of Indian Ocean and in the Malay Archipelago south of Java. These regions, therefore, become highly productive. We have, thus, seasonal fluctuations in the production of organic matter, and, as on land where crops are influenced by the monsoons, in our seas also the monsoons play an important role in the prospects of the phytoplankton crop, the basis of all food, on the magnitude of which the final harvest of fish will depend.

Food Chain

The enormous production of organic matter in the form of plants goes to cater to the requirements of hundreds of species of animals in all stages of development and sizes, the zooplankters, the larger plankters, the young of fish and even many adult fishes. In fact, there is an increase in the population of the herbivores and predators side by side with the increase in the phytoplankters, and often the plants are eaten up and one comes across only the animal population in the water. More the plant production, greater the survival rate all along the links in the food chain.

The largest mammal, the blue whale, inhabitant of the Antarctic, is a feeder of the small shrimp-like animal commonly known as *krill*; the krill is wholly dependent on the bloom of phytoplankters during the spring for survival and growth. And, when one considers the rate of growth of the whale, to weigh almost a 100 tons in three years, the quantity of phytoplankton to sustain the food of the whale may be imagined. The largest of fishes, the basking shark, is also a plankton feeder, chiefly on the tiny animal known as *Calanus* (a kind of water flea), and the latter thrives on the phytoplankters. The success of the herring fishery of the North Sea entirely depends on *Calanus*. The vicissitudes of this fishery in the past has affected the fate of several European nations. The prospects of our oil sardine, mackerel and prawn fisheries in India are entirely dependent on the bloom of phytoplankters on the west coast; a failure of these fisheries spells misery to thousands of fishermen. The constituents of the oceanic fisheries such as the tunas, depend on a host of small animals, crustaceans known as euphausiids, as well as cuttlefishes and small fishes for their food which in turn directly or indirectly are nourished by the phytoplankters.

The sea bottom, particularly on the continental slope, is inhabited by numerous animals, the smaller of which feed on the dead and decaying plankters raining down from the layers above. These in turn are eaten by prawns, crabs, the worms and many others which are fed on by the bottom dwelling fishes.

The oysters, barnacles and other attached animals are filter feeders. We have here the shortest food chain in which the organic production is utilized to the maximum with least loss, these animals being direct consumers of the production.

Magnitude of Organic Matter Production

It may be worthwhile to examine the magnitude of production of organic matter and its relation to commercial fish landings. It was estimated that during the period 1949-1954, the average landings of marine fish in India amounted to only 4,55,900 tonnes as against a production of 1,813,000,000 tonnes of organic matter. These results based on the standing crop have since been confirmed in experiments using radioactive carbon C^{14}, to measure photosynthesis. The increased exploitation since 1955 has only gone to reduce the gap towards the potential by 0.005 per cent In the intensively exploited areas elsewhere, this percentage is only 0.06 percentand F.A.O. experts believe that even here there is a prospect of a four-fold increase. Hence, the potential figure for the oceans is about 2.4 per cent and our landings represent only 0.03 per cent. This would indicate that our marine resources await intensive exploitation. In many of the other countries bordering the Indian Ocean exploitation of marine fisheries is even less than ours, on what is termed subsistence level.

The present total marine fish landings in India is hardly 1 in 50 of the world catch. The exploratory fishing carried out on the west coast by the C.M.F.R.I. during the last 6 years from on board R.V. VARUNA has revealed considerable potential resources of commercial fishes, prawns, and lobsters. The phenomenal growth of the sea food industry in recent years is solely due to the prawns, considerable quantities of which are exported. The wealth of our oceanic waters is further indicated by the long-line tuna fishing carried out by the Japanese in the Indian Ocean since 1952 with bases in East Africa and Madagascar. The Russian, Korean and Taiwanese vessels too have ventured so far away from their countries for fishing in the Indian Ocean. With suitable gears and crafts, there is no reason why India should not share in this wealth of the sea.

Indicators of the resources and locations. The problem that occurs next is where to look for fish in the vast oceans. It is very difficult, nay impossible, to lay down fixed guiding principles as conditions in the waters, the hydrosphere, are affected by water movements in currents, mixing up of waters of different qualities, upwelling, sinking, changes in nutrient content and dissolved gases, etc. in the same manner as life is influenced on land by meteorological and climatic changes, rainfall, drought and so on.

While much has been done to find correlations between

plankton crop and fisheries and to indentify indicator organisms in the temperate and arctic regions, we have not much knowledge about these relations owing to the paucity of investigations. Fishery research is of recent origin in India. Nevertheless, on the basis of existing knowledge some indications of location of the resources may be arrived at, indispensable for rational exploitation.

Owing to the horizontal displacement of upwelled water by currents, the plankters appear separated by time and space, the former depending on the rate of growth of constituent species and the latter the displacement during the time. The time required is short in a tropical environment such as ours owing to the higher metabolic rate and space depends on the direction and velocity of the currents.

During the S.W. monsoon, the water mass in circulation in the Arabian Sea and to some extent in the Bay of Bengal is the upwelled water. The circulation is from south to north along the African coast, then eastwards in the northern Arabian Sea and from north to south on the west coast of India. This water enters the Bay of Bengal and circulates clockwise and part of the upwelled water flows towards the Indonesian Archipelago.

Proximate to the area of upwelling, heavy phytoplankton production occurs and these are carried away by the current and during its course, in the water mass, the animals present consume this organic matter, thrive and breed and they in their turn are fed on and thus the constituents of the fauna and flora of the water mass change, reflecting the links in the food chain already discussed.

It is suggested that the most important factor which leads to fish aggregation in a tropical environment is the availability of food and basic productivity controls the distribution of fish; and it is possible that the fishes reach various areas along their route of migration at times, when, feeding conditions are favourable; in other words, fish catches coincide with plankton concentration.

In the clockwise circulation of the plankton rich water of the Arabian Sea, a number of convergence zones (zones where two flowing water masses meet and water tends to sink) and eddies occur; in these places, the plankters accumulate. The oil sardine and the mackerel, feeders on the plankters are to be sought for not far from the zone of upwelling near the shore on the continental shelf where smaller plankters are found. Migratory fishes are known to stay in eddies and run quickly between eddies for feeding. The predators of these fishes, the cat fishes, sharks and so on are to be found near these places.

Farther off, where on encounters, the larger plankters such as omnivorous and carnivorous copepods, euphausids, chaetognaths (arrow worms) and many others, their predators, the several species of tunas and billfishes and flying fish abound. This has been the experience of fishermen in the Pacific where the tunas occurred far away from the zone of upwelling. Fishing grounds of these are also located on topographically stationary eddies formed by islands or submarine banks, as found around the Laccadives.

There are a number of convergence and divergence (surface water displaced by wind or other forces leading to upwelling of bottom water) zones, the former more during the N.E. monsoon months owing to meteorological and other factors. Divergence leads to increased organic production. The convergences, situated as they are in areas rich in plankters brings about a concentration of these at these places indicating a potential fishing area. The convergences about the Equatorial zone in the Indian Ocean are well known long-line tuna fishing grounds. The convergence zones near the Laccadives and the Andamans would account for the tuna fishery there. The presence of spawners and juveniles in these areas are indications that they are rich in food and favoured by the adults.

Our knowledge of the bottom topography, submarine banks and ridges, etc., is rather meagre. These structures hinder the even flow of currents, cause eddies which lead to sinking of plankton rapidly than otherwise. As most of the midwater and bottom dwellers constituents of demersal fishery—have a food chain with the sinking matter as the first link, one could expect an abundance of fish in such areas. It may also be stated in this connection that the unconsumed matter accumulates at the bottom and in the course of ages is converted into hydrocarbons, a source of petroleum.

Set back to fisheries. Marine life is affected adversely sometimes. Rarely, it so happens that the upwelled water is very poor in oxygen content and this leads to mass mortality of fishes and other marine life. At times excessive bloom of phytoplankters takes place, so intense as to colour the water green, red, yellow, pink, according to the pigmentation of the organisms involved. Some of these organisms secrete toxins which affect adversely fishes and other life in the water. Fortunately, such occurrences are far between. But, of late, industrial pollution and disposal of radioactive wastes have created problems which again require attention of fishery scientists.

Marine fisheries research in India, though hardly two decades in existence, has accomplished much against great odds—paucity of equipment, facilities for work and above all lack of an ocean-going well equipped boat, a *research vessel*, the prime requisite of a Fisheries Research Institute. For over a decade, work area was

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