FISHERY RESOURCES OF THE INDIAN OCEAN*

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I. Introduction

INTEREST in Indian Ocean Fisheries has been a comparatively recent development in the history of world fisheries and has principally stemmed from efforts of countries like India to step up their supply of protein to their large populations. These efforts of the Asian countries have been assisted by United Nations Agencies, notably the Food and Agriculture Organization. A third contributory factor has been the efforts of countries with distant water fishing fleets to operate in the Indian Ocean. Pioneer work of this type has been the fishing effort of Japan in the Indian Ocean, particularly for tuna, and the more recent efforts of the Soviet Union at exploratory fishing. Australia, South Africa and India have been engaged in exploratory surveys in the regions of the Indian Ocean near their own coasts.

When the programmes of the International Indian Ocean Expedition were formulated, fisheries potential was used as an impressive argument to stimulate interest in the project in the Asian and African countries. A quarter of the world's population lives in countries bordering the Indian Ocean, largely in low nutritional standards in terms of calories and acute deficiency in terms of animal protein. Pressure on land use was acute in most countries and added food resources from the sea were clearly indicated as a much needed economic and nutritional corrective. Basic fisheries programmes and attendant biological surveys were included in the earlier draft proposals; physical oceanography was closely dovetailed to chemical biology and plankton studies. In spite of all these, the actual fisheries work accomplished during the expedition itself has been disappointingly small, a fact which is not unconnected with the lack of facilities for exploratory fishing in most ships which took part in the Expedition, with heavily weighted programmes in physical, chemical and geological work. The results of these studies need not be considered negative by those interested in fishery science because the expedition results are clearly bringing out many features of physical and chemical oceanography of the Indian Ocean which have close bearing on the location of fisheries resources, particularly the mapping of areas of upwelling and the movements of the low oxygen waters.

II. Previous Reviews

In a brief account as this, it will not be possible to evaluate critically all the available data but the broad features are given as have emerged from the various studies which are going on in different centres of marine research. Further exploratory and commercial fishing requires more critical evaluation of physical and chemical data collected on a synoptic basis to make fishing operations in specified regions economical. Following the International Indian Ocean Expedition, it is hoped that such critical work will be taken up by the Indian Ocean countries themselves within the forthcoming years.

III. Physical and Chemical Features of the Indian Ocean

Seasonal mixing of surface and deep waters as occurs in the colder latitudes does not occur in most parts of the Indian Ocean and one has to look for the areas of divergence and upwelling to find the turnover of bottom waters to the surface. Two areas of the Indian Ocean, the Red Sea and the Persian Gulf are regions of high salinity and temperature and of these, the higher salinity influences the Northern Arabian Sea. Apart from this, the intense evaporation in the northern part of the Arabian Sea is also responsible for the high salinity of the waters of this region. The Bay of Bengal on the other hand represents waters warmer than the Arabian Sea but with pronounced estuarine influence with several large rivers opening into it. The average salinities are lower here than in the Arabian Sea.

The southern half of the Indian Ocean has characteristics not unlike the southern basins of Pacific and Atlantic bordering on the Antarctic. From the fishery point of view it is noteworthy that for most parts of the entire Indian Ocean, the continental shelf is narrow.

One of the features of the Indian Ocean is the fact that it is largely influenced by the monsoons. The formation of the monsoons and related atmospheric phenomena have been discussed by other speakers at this Congress. The

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monsoon systems are specially pronounced in the Arabian Sea and the Bay of Bengal both the areas being entirely under the regimes of the south-west and north-east monsoons. The southern hemisphere is free from these large-scale wind systems except to a small extent towards west of Australia and to the east of South Africa.

The strong south-west winds during May to early September often deflect large masses of water from the surface and the replenishment of these by the deeper waters result in upwelling. One important area where upwelling following strong offshore winds occurs is the Somali coast, where, in addition, a powerful current going northwards of East Africa in a clockwise direction grazes Arabia, Pakistan and even up to Indian West Coast. This summer pattern is reversed in the north-east monsoon time when offshore winds off the Kathiawar Peninsula result in upwelling particularly in the Gulf of Cambay (Jayaraman and Gogate, 1957).[7] Similarly large-scale upwelling occurs during the south-west monsoons in the south-west coast of India, there is the complex phenomenon of several physical factors acting together the net result of which is the large-scale movement of high nutrient laden, low temperature and low oxygen waters to the surface (Panikkar and Jayaraman, 1956).[2]

One physical feature of the Indian Ocean which has been noted in former years but has come to special comment and observations during the International Indian Ocean Expedition is the regime relating to waters and bottom areas having little or no oxygen. Certain areas in the Arabian Sea have been known as azoic areas from the time of the John Murray Expedition (Sewell, 1955)[5] and several such areas have been noted by Soviet Ships where the azoic conditions prevail in several parts of the western shelf in Gulf of Cambay and off Arabia.

It has been observed by most of the ships participating in the Indian Ocean Expedition that the waters of the Arabian Sea are deficient in oxygen reaching the minimum by about 200–500 meters. It has further been observed by Indian workers and by other ships that the actual oxygen minimum layer comes fairly close to the surface towards the west coast of India during the south-west monsoon regime (Panikkar and Jayaraman, 1966). More critical work is needed to correlate wind force and upwelling. The movements of the oxygen minimum layer may have the beneficial effect of concentrating populations of fish towards the coast in certain seasons but it is equally possible that in the open ocean the surface areas of high productivity do not reach their culmination into profitable fisheries owing to the calamitous effects of low oxygen water. These may well be the cause of large-scale fluctuations in certain fisheries as of the oil sardine of the Indian West Coast and of large-scale mortalities.

IV. Biological Aspects of the Indian Ocean

The major part of the Indian Ocean from the fisheries point of view is composed of a tropical Northern two-thirds of the ocean which is continuous in faunal characters with the larger marine Indo-Pacific area which is a distinct marine zoogeographical division. This area covers the Arabian Sea, Bay of Bengal, Eastern Central Indian Ocean and the smaller seas associated with the eastern archipelago and the equatorial region. The other regions which have specific biological characteristics are the temperate South African region which has characteristic temperate fisheries, the West Australian region which has comparable but different fisheries and an East African tropical region which has tropical fisheries, different from the Indo-Pacific. The Gulf of Aden has certain specific fishery characters but in the main, the commercial species are dominant elements of the Indo-Pacific fauna. Finally, there is the oceanic fishery consisting mainly of stocks of tuna, sail-fish, etc., which assume considerable importance in the Eastern Central Indian Ocean.

The tropical Indian Ocean waters are likewise regions where extensive coral reefs are found with several hundreds of coral islands. While the reefs have contributed much to the remarkable diversity of animal and plant life in the Indian Ocean harbouring several thousands of species forming a reef fauna and flora, it has not contributed to large-scale fishing banks. Even good stocks on reefs are difficult to exploit owing to hazardous fishing on reefs.

The principal features relating to fisheries on the Indian Ocean are that the pelagic and mid-pelagic species dominate the commercial catches with a corresponding reduction in numbers of the ground fish suitable for large-scale trawling. The gadoids which form extensive fisheries in North Atlantic and North Pacific are conspicuous by their absence; this group is represented only by one genus (*Bregmaceros*) whose yield is negligible. Similarly the flat fishes also occupy a low place in the total production and many of them are of small size and confined to the inshore areas.

The southern part of the Indian Ocean to the east of Southern Africa and to the west of Australia, however, present characteristics which are common with the temperate zones with an increased predominance of ground species including the larger gadoids and lobsters.

Most commercial species are characterised by having comparatively longer breeding seasons and one of the peculiarities of fish stocks is the predominance of the younger age groups in the commercial catches. According to a rough calculation, nearly 3/4ths of the entire catches in the Indian Ocean are taken up by fish not more than three years old and even among this, the zero year class is a major contribution to the fisheries in the warmer regions where the rate of growth is rapid. It is in this context that the close relationship between areas of upwelling, high productivity and dense plankton assume special significance in the location of commercial fisheries.

A feature of the Indian Ocean fish fauna in relation to the coastal fisheries whose importance is not often appreciated is that throughout the Indo-Pacific there are important species which are primarily found in the sea and breed in the sea and coastal waters, but ascend estuaries and coastal lagoons when they are young. Annual migrations of young fish of this type take place throughout the coastline and the yield from their harvest in the areas immediately adjoining the coastline is very considerable. To this category belongs the well-known Milk-fish, *Chanos chanos,* species of mullet and of penæid prawns. Species like *Hilsa* which are migratory estuarine fish are important on the coasts of Pakistan and India.

In the Indian Ocean are the areas like Persian Gulf which are shallow platforms forming continental shelves like the North Sea but unfortunately the productivity of these areas is very low. The indications are, therefore, that speaking for the whole area the prospects for trawl fishing are limited except in certain regions where specialised conditions seem to favour such efforts. Areas to the west of Port Okha and west of Ceylon, some regions of the Gulf of Oman and the western coast of Australia and eastern and southern coasts of South Africa are probably areas where efforts in trawling would be commercially successful.

V. Fisheries Yields from the Indian Ocean

Production of fish in the Indian Ocean during the past 15 years or so has, according to FAO fisheries statistics, increased from 1·3 million tons to about 1·8 million tons in 1964 although a still higher figure of 1·9 million tons was touched in 1960. These figures are not likely to be complete. Rass (1965)[4] has estimated the yield at about 2·0 million tons but my own estimate of current production is of the order of 2·5 million tons, but in the following discussions FAO figures have been taken as the basis. The trend of the landings also shows that the increase has taken place both in western and eastern Indian Ocean; but since the output from the western Indian Ocean is greater than the eastern, the present total production is roughly of the order of 1 to 1·1 million tons in the western Indian Ocean, as against 0·8 million tons on the eastern Indian Ocean. In relation to total world marine catch, however, the increase in the Indian Ocean is far from impressive and in fact the percentage contributed by Indian Ocean to the world catch has decreased from about 7% in 1949 to 5% during the past few years. The production from the western and eastern areas in relation to the world total catch is of the order of 3% for the western Indian Ocean and 2% for the eastern Indian Ocean. Considering 1957–59 as the base year at the Index Number 100, the marine fisheries of the Indian Ocean in 1964 has registered an increase to 112, as against the world marine catch increase to the Index Number of 157. These figures show that increase in yield from Indian Ocean has not kept pace with the increase in world catch and indicates the scope of further output. Even assuming that the rate of increase as has taken place in other parts of the world is all that is possible, we should expect the 2·5 million tons to improve to 3·6 million tons with better technology and effort. The rate of increase at least for quite some years could be substantial with more effort because many fisheries have hardly been touched at all, many offshore stocks are not exploited and many inshore stocks are underfished.

At present the major fish-producing country of the region is India with an yield of about 900,000 tons.

The production from the East African countries is at present of the order of 65,000 tons which is shared by 12 countries. The largest yield is from Tanzania, the total production from Zanzibar and Tanganyika accounts for nearly 20,000 tons. Next in importance is the Malagasay Republic 15,000 tons (average for 1961–63) and Ethiopia, mostly on the Red Sea side at 11,000 tons. It is interesting to note

that nearly 45% of the contribution from East African countries are demersal fisheries with the sardines ranking next (18·5%). A very promising area of the African coast is the Mozambique coast as judged by productivity, where the present yield is only 4,000 tons. The Somali region, Gulf of Aden and the areas of Gulf of Oman are promising areas for further effort. This is borne out by nutrient distribution and primary production studies. One of the clear tasks will be to differentiate between pelagic, mid-pelagic and demersal stocks and to assess their intensity, and to establish the niche at which the high productivity results in good commercial fisheries.

VI. Future Prospects of Indian Ocean Fisheries

What then are the prospects for expanding the existing fisheries? It may be argued with reasonable certainty that productive regions like the Andaman Sea, West coast of Burma, Coasts of Ceylon, West Coast of India, Coast of West Pakistan, Gulf of Aden and Oman, Somali Coast, South African and West Australian coasts are all areas where substantial increase in production is possible from stocks already known and partially exploited. Gulf of Aden, Somali region and South-West Coast of India deserve special mention if phosphates, chlorophyll and phytoplankton are taken into consideration. Some authors have calculated a scope of increase nearly as much as 10 times the present landings and this increase in the yield of the neritic pelagic complex of fishes appears feasible, whereas a much larger increase based on new stocks is quite possible in the newly found productive areas like the Gulf of Aden, Gulf of Oman and Somali coasts.

As regards increased capacity for trawler yields the scope really lies in fishing beyond the marginal seas on the shelf and on the slope of the shelf. Here, experience obtained on the west coast of India in the Kathiawar area might well be indicative of what might be found in the other Arabian Sea areas where the shelf is productive. From trawler fishing the increase may not be much in terms of total yield but substantial in terms of value.

Another bright future is with reference to oceanic fisheries—tunas and other larger Scombroids. Here we may expect a substantial increase from the present 150 thousand tons per annum. The Gulf of Aden is a most promising area for long lining and purse seining for tuna showing some of the highest catch rates recorded and the average Indian Ocean yield of tuna obtained by Japanese vessels are higher than in the Pacific and Atlantic.

The increase in Crustacean fisheries would take place by bringing many areas to fishing but with increased attempts to find out the deep water prawns in the farther waters of the shelf and even on the slope. Prawns which are capable of utilising the coastal inlets for quick growth and development already feature largely in the crustacean production of some Indian Ocean countries and it is to be expected that these practices will become widely spread, based on the breeding oceanic stocks and the young zero year class growing rapidly in coastal belts.

A fishery which is now of low magnitude but which offers great scope in the future relates to the Mollusca which are capable of giving very high yields from the shallow coastal areas of the tropical seas. The yield per acre is exceptionally high and may figure very considerably in future years.

The general picture emerging out of the present information on the fisheries resources of the Indian Ocean and the oceanographic data which are accumulating as a result of the International Indian Ocean Expedition is that there is much scope for increased production from the Indian Ocean than the present rough yield of about 2·5 million tons. Increase in pelagic fisheries is possible in areas which have been diagnosed as areas of divergence and upwelling, higher dissolved nutrients, and higher plankton biomass.

Apart from the well-known pelagic fisheries and the shoaling species of sardines and the scombroids the indications are that the actual fish stocks with reference to an individual species are not of a large magnitude. Instead, there exist a large number of smaller fisheries composed of species with wide range of distribution but forming commercial fisheries in areas widely distant from one another. In many areas of the Indian Ocean the large increase is to come from exploitation of the waters adjoining the coast directed to utilize these miscellaneous fisheries. The technological needs for substantial increase from these fisheries are :—

1. Modern techniques of fish finding and scouting of large concentrations of scombroids and clupeoids in the highly productive areas.
2. Methods to concentrate the somewhat sparse populations of miscellaneous groups of fishes by entirely new techniques

involving the use of light, sound or electricity to make the yield economical.

3. Intensive studies on selected parameters like temperature and oxygen distribution to locate the fish stocks and their area-wise distribution in different seasons.

It was mentioned in an earlier section that the present yield from the Indian Ocean may roughly be put as 2·0 million tons, and taking into account subsistence and unaccounted sources, as about 2·5 million tons. Fisheries expansion is not entirely determined by the availability of resources but influenced by the needs, capabilities and technological improvements taking place in any country. Experience has shown that this change is not rapid. There are the extremes of very slow development at one end where changes are imperceptible and at the other of rapid introduction of modern fishing craft and gear and all attendant facilities. Both these have acted in the Indian experience of marine fish production, where the general trend is that the output is roughly doubled during a 10-year period. It may not be far off the mark if this rate of development is taken as average for most other Asian and African countries, where there is the need for such expansion, economic support and technical feasibility. In this case the output from the Indian Ocean could roughly be indicated as about 20 million tons per annum towards the close of this century. This is apart from large-scale individual fisheries for oceanic stock like tuna, sardines or mackerel mainly in the upwelling areas where newer and imported technology and factory ships might make substantial catches possible. The outlook for the future of Indian Ocean Fisheries is, therefore, one of moderate optimism. The hope that Indian Ocean can provide a substantial contribution to the food supplies of the bordering countries is fully backed by the newer knowledge of oceanography.

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A RAPID METHOD OF SPECIFIC IDENTIFICATION OF JAPANESE ENCEPHALITIS—WEST NILE SUBGROUP OF ARBOVIRUSES

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CASALS (personal communication, 1957) described a simple complement fixation (CF) test with crude antigens and mouse hyperimmune sera, as a useful tool for placing a new isolate of arbovirus in a group (Casals' group A, B, C, etc.). Because of its great simplicity, the method, often referred to as 'quick CF', with a few modifications, has been extensively used at the Virus Research Centre (VRC), Poona, for rapid identification of new isolates as well as in experimental transmission studies. Briefly, a 10% suspension of the infected, infant or adult mouse brain is prepared in saline (0·9%) and centrifuged at 5,000 rpm for 60 minutes. The undiluted supernatant is immediately tested as a CF antigen with two-fold serial dilutions of hyperimmune sera prepared in mice. Although the mouse brains are frequently stored for long periods of time at — 50° C. the suspensions are always prepared at the time of use.

By this method, it has been easy to distinguish Kyasanur Forest disease and dengue viruses from one another as well as from Japanese encephalitis (JE) and West Nile (WN) viruses, all group B arboviruses, known to be present in India. However, it has not been possible to distinguish between the viruses of the JE-WN subgroup by this technique. Since these two viruses are known to occur simultaneously in North Arcot District, Madras State (VRC unpublished data) and might also be occurring together in other parts of India, it was thought worthwhile to develop a relatively

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