# A QUANTITATIVE ASSESSMENT OF THE POTENTIAL FISHERY RESOURCES OF THE INDIAN OCEAN AND ADJOINING SEAS

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The Indian Ocean as conventionally described includes the Antarctica also, and has an area of 74·917 million sq km (Sverdrup *et al.*, 1946). The authors for the purpose of this study have taken the region between 20° and 120° E longitudes and from the Asian land mass in the north to 45° S latitude. The area thus considered covers over 51 million sq km or roughly two-thirds of the conventional Indian Ocean.

On its periphery live about 500 million people whose per capita consumption of fish does not exceed 1 to 2 kg per year, which is only one-tenth of that of some developed countries. The present catch from the countries bordering the Indian Ocean is about 2·1 million tonnes according to FAO Yearbook, and 2·5 million tonnes according to Panikkar (1967). This in terms of unit area is about one-fourth to one-sixth of the present yield from the Atlantic and Pacific Oceans (Shomura *et al.*, 1967). Hence when the International Indian Ocean Expedition (IIOE) was conceived the main emphasis, apart from understanding a least-known ocean, was the assessment of the fishery resources for increased utilization to augment the protein food of the people in the surrounding regions.

As a first step the distribution of zooplankton biomass in the Arabian Sea, Bay of Bengal and the entire Indian Ocean was studied (Prasad, 1968a, b). This was based on the volumetric analysis of the standard zooplankton samples deposited at the Indian Ocean Biological Centre. This study provided useful information on the relative productivity of the various regions of the Indian Ocean. Based on this, Prasad (1969) discussed the distribution of zooplankton biomass in the Arabian Sea and Bay of Bengal, and the fisheries of the regions. These studies provided a general picture of the areas rich in plankton and the relative magnitude of the fishery resources as they existed. In this paper, based on the zooplankton data, a quantitative estimate of potential yield of fish has been worked out along with an independent assessment using $C^{14}$ primary productivity data, tracing the carbon production through the various trophic levels. These appraisals have been compared with a review of the results of exploratory surveys conducted by various agencies at different periods in the Indian Ocean region.

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As pointed out by Riley (1963), the upper end of the food chain presents certain problems aside from its complexity, and it is only in certain cases that the true biomass of fish population can be assessed accurately. In a study of this nature covering a vast area, when the sampling had not been adequate to offset the vagaries of seasonal variation, absolute values have little meaning. Hence the authors have only tried to make a broad appraisal of the potential harvest from the Indian Ocean so as to examine whether the optimism which launched this great international venture has been justified.

## SHALLOW-WATER AREAS IN THE INDIAN OCEAN

Even though oceanic fisheries have become a major contributing factor in the world production of marine fish, for countries bordering the Indian Ocean which do not have large mechanized fishing fleet capable of operating far away from their ports, the fisheries of shallow-water areas are of primary interest. The shallow areas over the shelf (<200 m) in the Indian Ocean are just over 307 million hectares (Table 1).

TABLE 1. AREAS OF SHALLOW WATER IN THE INDIAN OCEAN (UNDER 200 M)

| | Regions | Estimated area in million ha |
|---|---|---|
| 1. | East African Coast (from Cape Agulhas to Lat. 12°N Long. 51°E) | 26·64 |
| 2. | Arabian Sea (from Lat. 12°N Long. 51°E to Cape Comorin) | 45·72 |
| 3. | Bay of Bengal (from Cape Comorin to Thailand-Malaysia border; includes Ceylon, Andamans and Nicobar) | 51·38 |
| 4. | Indonesia—Australia (north-west coast of Sumatra, south coast of Indonesian Islands, West Australia from Long. 130°E on the north coast to 129°E along the southern coast, islands of south of Sumatra) | 98·20 |
| 5. | Red Sea | 21·00 |
| 6. | Persian Gulf | 26·82 |
| 7. | Oceanic Islands and Banks Madagascar, Other Islands and Banks (includes Maldive Islands, Seychelles Islands, Comoro Islands, Reunion Islands, Mauritius Islands, etc) | 37·37 |
| | Total | 307·13 |

The east coast of Africa has a narrow continental shelf at its northern end, widening to 160 km at the southern-most tip. The coastal regions of Mozambique, Tanzania and Kenya are fringed with mangrove and coral reefs. The Red Sea, Gulfs of Suez and Aqaba region are bounded by narrow reefs. Gulf of Persia is extremely shallow. West Pakistan, west coasts of India and Ceylon have prominent shelf, whereas on the east coast the shelf is narrow. The coasts of Burma, Thailand

and Malaysia have a wide shelf area with mangrove swamps. The west coast of Australia has narrow shelf, less than 65 km wide in the south-western part, whereas northward the shelf becomes wider. In the north-west area of the continent the shelf exceeds 320 km in width. The western Indian Ocean Islands (Comoro, Mauritius, Reunion, Seychelles, Chagos, etc.) have banks which are of both volcanic and coral reef type.

## PRODUCTION IN THE OCEANS AND TREND OF FISHERY

To obtain an adequate notion of the importance of primary productivity in the biological household of the sea, it is necessary to estimate the total turnover of matter and the yield in terms of fish. Riley (*vide* Rabinowitch, 1945) showed that the production of organic matter does not change much from the equator to the Polar circle and that the average of all measurements is 375 kg of organic carbon annually per sq m corresponding to 3·75 tonnes per ha. Hence according to Riley's estimate for $361 \times 10^6$ sq km of sea the production amounts to $15 \cdot 5 \times 10^{10}$ tonnes which is eight times higher than the carbon fixation calculated for land. But Steemann Nielsen (1954) questioned the validity of this estimate. From *Galathea* Expedition Data, he estimated the annual production of the hydrosphere (*vide* Steemann Nielsen and Jensen, 1967) to be $1 \cdot 2 - 1 \cdot 5 \times 10^{10}$ tonnes of carbon (net production after allowing 40 per cent for respiration), which was practically the same as the earlier estimate for land. Ryther (1959) considered this estimate to be lower as it has been based on single observations and does not include seasonal maxima. His own estimate is that the seas are twice as productive as land. If a total annual production of $1 \cdot 9 \times 10^{10}$ tonnes of carbon for all the seas is assumed (*vide* Schaefer, 1965), the present fish production of 54 million tonnes would represent only 0·03 per cent of net production. According to Steemann Nielsen and Jensen (1957), in eutrophic areas at higher latitudes, e.g. the North Sea, about 0·2–0·3 per cent of the carbon annually fixed by the plankton algae is taken every year by the fishermen. With improved methods of catching, the optimum seems to be at 0·4 per cent. Such a high percentage of yield is possible only in coastal areas where the main fishery harvest consists of anchovies, sardines, herring and the like, some of which feed almost entirely on phytoplankton and others which feed on a mixture of phyto- and zoo-planktons. When the harvest is from higher trophic levels the potential yield is likely to be less.

Schaefer (1965) recently attempted to estimate the potential yield of the sea by calculating the harvestable crop from the net carbon production and its subsequent transfer through the food web. He considers a production of $200 \times 10^6$ tonnes of fish for the world oceans as reasonable and probably conservative. That would mean a four-fold increase from the present level of exploitation. Some experts believe that with the present trend of increase in the marine-fish production an increase to 100 million tonnes by the end of this century should be possible. The target set for 1970, viz. 55 million tonnes of marine fish, has nearly been achieved even in 1967 when the marine-fish production was estimated at 54 million tonnes (FAO Yearbook, 1967).

The Indian Ocean has been a comparatively under-exploited area. The present yield is roughly 2·5 million tonnes and it is believed that the output could reach 20 million tonnes per annum towards the close of this century (Panikkar, 1967).

Shomura *et al.* (1967), however, consider that the scope for expansion in the Indian Ocean is restricted to certain areas only.

Since the general level of chlorophylls (Humphrey, 1966) and productivity in all the oceans is more or less uniform, the present yield as a ratio of net production for different regions is given in Table 2.

TABLE 2. PRODUCTION RATES AND FISH YIELD

| Habitat | Area in sq km × $10^6$ | Average carbon fixation (gross) gC/m²/day | Total carbon production (net) per year × $10^{10}$ tonnes | Yield in tonnes per km² | Yield ratio as %C |
|---|---|---|---|---|---|
| Oceans | 361·0 | 0·20 | 1·2–1·5(1) (1·9)(2) | 0·11(3) | 0·030 |
| Pacific | 179·7 | 0·20 | 0·75 | 0·14(3) | 0·030 |
| Atlantic | 106·5 | 0·20 | 0·45 | 0·17(3) | 0·040 |
| Indian Ocean | | | | | |
| Western | 29·0 | 0·24 | 0·39 | 0·03(3) | 0·005 |
| Eastern | 22·0 | 0·19 | | | |
| Continental shelf (Indian Ocean) | 3·1 | 0·85 | 0·056 | 0·55 | 0·035 |

(1) Steemann Nielsen and Jensen (1957)
(2) Schaefer (1965)
(3) From Shomura *et al.* (1967)

## PRIMARY PRODUCTION IN THE INDIAN OCEAN

The data on primary production has been obtained from the cruise reports of *Anton Bruun* for the western Indian Ocean and Bay of Bengal, and of *Dimantina* for south-eastern Indian Ocean. For the west and south-east coasts of India and Laccadive Sea data from the Central Marine Fisheries Research Institute have been taken. The results of *Galathea* (Steemann Nielsen and Jensen, 1957), *Vitiaz* (Kabanova, 1961) and *Africana II* (Mitchel-Innes, 1967) have also been considered for computing the productivity of the Indian Ocean. For the oceanic regions the available data have been pooled and the average taken. Isolines constructed with these data have been used for estimating the productivity of the regions (Fig. 1).

The measurements by *Galathea* of primary production in the Indian Ocean were the first ones made with $C^{14}$. All stations at middle latitudes in the western part outside the continental shelf were characterized by a production rate between 0·1 and 0·2 gC/m²/day, the value normally found in tropical and subtropical oceanic regions in the absence of any pronounced admixture of nutrient-rich water from below. Over the shelf off Beira the average was 0·51 gC/m²/day. On the Agulhas Bank water from the lower boundary of the photosynthetic zone showed three and a half times the rate of production from that of the surface under constant illumination, indicative of a distinct ascent of nutrient-rich water to the photosynthetic layer (Steemann Nielsen and Jensen, 1957). In the south equatorial current a relatively high production

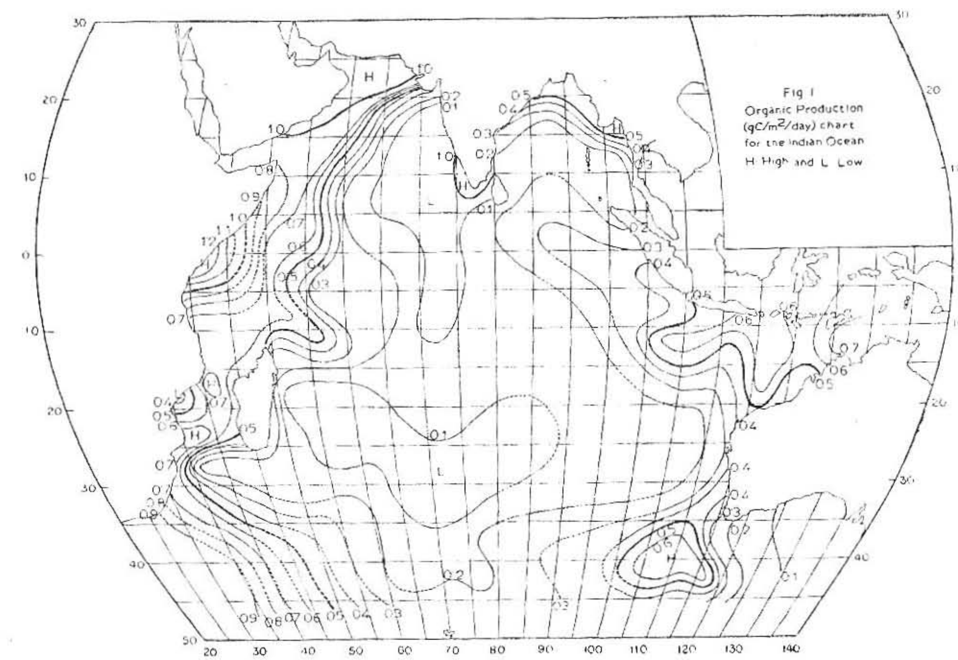


FIG. 1.

rate, 0·22–0·23 gC/m²/day, was found. The coast of Ceylon has a high production rate. Very high values were observed south-east of Java and this region has been shown recently to have upwelling, fairly high concentration of inorganic phosphate at the bottom of the euphotic layer and a high plankton biomass (Wyrtki, 1962). Summarizing all the *Galathea* measurements in the equatorial current systems of Indian Ocean, Steemann Nielsen and Jensen (1957) concluded that the rate of production is moderately high in the whole region of the equatorial current systems and in restricted areas very high rates of production are found.

Kabanova (1961) reported that primary production in the open part of the ocean was low and did not exceed 0·01–0·03 gC/m²/day. An increase in the value of primary production was observed in coastal waters and in the zones of ascent of deep water. In the Banda Sea the production reached 0·236 gC/m²/day, while on the Australian shelf the value increased up to 0·45 gC/m²/day. In the African-Madagascar region it was 0·072 gC/m²/day. The Arabian Sea water was characterized by an especially high productivity connected with the presence of regions of deep-water ascent.

For the western Indian Ocean, Ryther *et al.* (1966) observed two large areas of low productivity, one to the north extending from 80° to nearly 60° E Long., and from the Indian Continent to about 5° S Lat., and another from 10° to about 40°S Lat. and from 80° Long. nearly to the African coast south of Madagascar. *Anton Bruun* measurements do not include any from near the coast. Nair *et al.* (1968) found that the level of organic production is high towards the coast and becomes less sea-ward. Values over 2·0 $gC/m^2/day$ are obtained within 50 m depth. Over the Wadge Bank at a station 38 m deep, the production rate was 2·09 $gC/m^2/day$. Just below the surface the rate per unit volume was 12 $mgC/m^3/hour$, suggesting a constant replenishment of nutrients. The highest value of 4·55 $gC/m^2/day$ was observed at a station on the Wadge Bank in September. The annual rate of gross production was 434 $gC/m^2$ on the shelf within 50 m depth, 157 $gC/m^2/year$ between 50 and 200 m and 50 $gC/m^2/year$ outside the shelf.

Ryther *et al.* (1966) noticed moderately productive waters (0·26–0·50 $gC/m^2/day$) between 5° and 10°S Lat. Pockets of high productivity (>1·00 $gC/m^2/day$) were noted along the south-east coast of Durban, Laurenceo Marques and Beira. On the seaward side of Agulhas Current relatively low levels of productivity were encountered.

North of the equator and into the Arabian Sea the level of organic production increases to the north and west, reaching exceptionally high values off the coasts of Saudi Arabia and West Pakistan. The average for 23 measurements in that region was more than 1·0 $gC/m^2/day$, with a maximum of 6·4 $gC/m^2/day$ observed off the south-eastern tip of Arabia. This value is the highest so far recorded from the oceans. Based on these measurements, Ryther *et al.* (1966) calculated that for the western Indian Ocean, where the *Anton Bruun* survey was carried out for an area of $23 \times 10^6$ sq km (about half of the Indian Ocean region now being considered, or one-third of the Indian Ocean as conventionally mentioned), the annual productivity is $3 \times 10^9$ tonnes of carbon which gives an average of 0·35 $gC/m^2$. But because of the great contrast in the relative productivity in this region the average value has not much significance. About half of the total production occurred in 20 per cent of the area surveyed.

Mitchell-Innes (1967) found for the region off South Africa, between latitudes 26° and 47°S, values ranging from 0·03 to 1·08 $gC/m^2/day$. High productivity was observed (>0·5 $gC/m^2/day$) in Delgoa Bay and off Port Elizabeth. Burchall (1968 a, b) observed values ranging from 0·02 to 0·94 $gC/m^2/day$ in the Agulhas Current region off Natal. Areas of high primary production were located in the vicinity of the continental shelf and also at the eastern boundary of the Agulhas Current. The average net production for the western half of the Indian Ocean is a little higher than the eastern half*. Over the shelf the annual average is more than double that of outside.

Allowing 40 per cent of the organic production for respiration, the average net production for the western and the eastern half of the Indian Ocean are about 0·24 and 0·19 $gC/m^2/day$, respectively. The difference is mainly brought about by the high rates of production obtained on the western Arabian Sea and the continental shelf areas on the west coast of India. The net production of carbon for the western half comprising $29 \times 10^6$ sq km is $2·3 \times 10^9$ tonnes of carbon per year and that for the eastern half comprising $22 \times 10^6$ sq km is $1·6 \times 10^9$ tonnes a year. These are, however, from the mean values including the oceanic regions.

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*80° E Long. is taken as the boundary separating the western and eastern Indian Ocean.

If the present level of exploitation for the oceans in terms of carbon is taken into consideration, the total yield works out to only 0·03 per cent of the net production. The present yield of 2·1 million tonnes of fish from the Indian Ocean and adjacent seas in terms of carbon is about 0·005 per cent, hence a six-fold increase seems possible to bring the level of exploitation to that of Atlantic and Pacific Oceans in view of the general level of productivity.

On the continental shelf the rates are uniformly high during most part of the year. The mean net production is 0·51 $gC/m^2/day$. This value is only minimal in view of the results of experiments conducted at several shelf stations for prolonged periods. As has been pointed out earlier, values over 1·0 $gC/m^2/day$ are often met with in near-shore stations within 50 m depth, especially during upwelling. Hence the annual net production for $3 \cdot 1 \times 10^6$ sq km of the shelf area would amount to $560 \times 10^6$ tonnes. Thus, approximately 6 per cent of the area produces one-seventh of the entire organic carbon in the Indian Ocean. In eutrophic coastal areas where it is possible to exploit 0·2 to 0·3 per cent or even up to 0·4 per cent of the carbon production, the minimum yield over the shelf itself would amount to $11 \times 10^6$ tonnes. Hence theoretically a six-fold increase from the present level of exploitation should be possible even from the stocks available within the continental shelf. To test the tenability of this hypothesis, the results of exploratory surveys conducted by various agencies at different periods were examined. Before giving an assessment of the potential yield based on the various exploratory surveys, the details of present yield and its composition are given below.

## PRESENT YIELD AND ITS COMPOSITION

The average annual yield from the Indian Ocean region is a little over 2·1 million tonnes (FAO Yearbook, 1967). The contribution from the East African coast region is about 58·7 thousand tonnes. The country-wise details (in thousand tonnes) are as follows: South Africa, 3·0; Mozambique, 5·8; Tanzania-Tanganyika, 16·8; Tanzania-Zanzibar, 10·1; Kenya, 6·2; Madagascar, 9·8; Mauritius, 1·4; Seychelles, 1·5; Comoro Islands, 1·6; and Reunion Islands, 2·5.

The average yield from the Arabian Sea region is about 9,39,600 tonnes; the country-wise break-up (in thousand tonnes) is as follows: Somalia, 4·5; French Somaliland, 0·7; Federation of South Arabia, 52·2; West Pakistan, 117·2; West Coast of India, 648·8; Laccadives, 0·7; Maldives, 15·5; and Muscat and Oman, 100·0.

The average yield from the Red Sea region is about 45,300 tonnes. The country-wise break-up (in thousand tonnes) is: Ethiopia, 12·8, Israel (Eilat), 1·3; Jordan, 0·2; Kamaran Islands, 0·5; Saudi Arabia, 5·0; Sudan, 1·3; U.A.R., 16·7; Yemen, 2·5; and Federation of South Arabia, 5·0.

The share of Persian Gulf area to the Indian Ocean catch stands on an average at 47,800 tonnes; the country-wise break-up (in thousand tonnes) of which is as follows: Iran, 16·9; Iraq, 1·1; Kuwait, 11·7; Qatar, 0·6; Trucial-Oman, 12·0; Saudi Arabia, 4·0; and Bahrain, 1·5.

The average annual catch from the Bay of Bengal at present is about 7,06,900 tonnes; the country-wise details (in thousand tonnes) is: east coast of India, 212·4;

East Pakistan, 46·6; Burma, 257·0; west coast of Thailand, 23·9; west coast of Malaysia, 70·2; Ceylon, 96·5; and Andaman and Nicobar Islands (India), 0·3.

The approximate average annual yield from the Indian Ocean portion of Indonesia is 1,75,000 tonnes and that of West Australia is about 12,200 tonnes.

Besides the above, an estimated 1,50,000 tonnes, mostly consisting of tunas and billfishes, are taken from the oceanic fishing in the Indian Ocean.

The above figures indicate that about 75 per cent of the present annual yield comes from the Arabian Sea and Bay of Bengal, which comprises about one-third of the total Indian Ocean area. This focuses the present uneven development of fisheries in the various regions of the Indian Ocean. Taking country-wise, India alone accounts for nearly 40 per cent of the total annual marine fish yield of the Indian Ocean region.

Detailed species composition of the annual yield is not available for most of the countries in the region. Detailed variety-wise compositions are available for Ceylon, India and Pakistan (FAO Yearbook, 1967), and these figures have been directly used in the estimation of the composition of yield of Indian Ocean region. Estimates for the whole countries as in South Africa, Malaysia, Australia and Thailand are available, whereas estimates for the countries along the Indian Ocean portion are not available. Shomura *et al.* (1967) gave the data on the composition for the Indian Ocean portion of Malaysia, Thailand and Australia. For other countries in the region, the composition has been worked out from the data given in Tables of Section C of FAO Yearbook. Because of these limitations, the variety-wise composition for the region can be given only according to the broad groups adopted by the FAO. The composition of various groups along with the associated percentages is given in Table 3.

TABLE 3. VARIETY-WISE COMPOSITION OF YIELD FROM INDIAN OCEAN AND ASSOCIATED PERCENTAGES

| Sl. No. | Groups | Average yield (in 1,000 tonnes) | Percentage |
|---|---|---|---|
| 1. | Flounders, halibuts, soles, etc. | 9·5 | 0·44 |
| 2. | Cods, hakes, haddocks, etc. | 5·5 | 0·26 |
| 3. | Red fishes, basses, congers, etc. | 410·9 | 19·24 |
| 4. | Jacks, mullets, etc. | 60·7 | 2·84 |
| 5. | Herrings, sardines, anchovies, etc. | 591·4 | 27·69 |
| 6. | Tunas, bonitos, skipjacks | 228·5 | 10·70 |
| 7. | Mackerels, billfishes, cutlass fishes, etc. | 182·7 | 8·56 |
| 8. | Sharks, rays, chimaeras | 106·2 | 4·97 |
| 9. | Unsorted and unidentified fishes | 203·9 | 9·55 |
| 10. | Crustaceans | 265·2 | 12·42 |
| 11. | Molluscs, etc. | 70·1 | 3·28 |
| 12. | Sea cucumbers, urchins, etc. | 0·9 | 0·05 |
| | Total | 2,135·5 | |

The group consisting of herrings, sardines, anchovies, etc. contribute 27·69 per cent of the total catch from the Indian Ocean (Table 3). About 60 per cent of the catch of this group is landed in India. They are also landed in substantial quantities in the Persian Gulf area and along the coasts of Federation of South Arabia, Ceylon, Burma and Indonesia. *Sardinella longiceps*, the oil sardine, is the most important single species belonging to this group, and in India it accounts for nearly 70 per cent of the landings of this group.

Next in importance is the group consisting of red fishes, basses, congers, etc. Their landings account for 19·24 per cent of the total yield from the Indian Ocean. This group of fish is landed in varying quantities in almost all countries of the Indian Ocean region. India accounts for the largest share of nearly 45 per cent. Substantial landings also take place in Federation of South Arabia, Muscat-Oman, Pakistan, Burma, Ceylon, Malaysia and Indonesia. In India, out of an average landing of 1,85,000 tonnes, Bombay duck accounts for 77,000 tonnes, silver bellies for 44,000 tonnes, jewfish for 26,000 tonnes, catfishes for 23,000 tonnes, perches for 12,000 tonnes, and eels for 2,000 tonnes.

The third important group in order of landings is crustaceans, which account for 12·42 per cent of the total yield. Out of an average annual landing of about 2,65,000 tonnes, India lands about 91,000 tonnes mostly consisting of shrimps. Substantial landings take place also in Pakistan, Malaysia, Indonesia and Australia.

Tunas, bonitos and skipjacks form the next important group and account for nearly 10·70 per cent of the total yield from the Indian Ocean. More than 60 per cent of these are caught from the highseas by countries outside the Indian Ocean region, notably by Japan and the rest by the countries of the region from the coastal areas. The most important landings take place in Ceylon, Muscat-Oman, Maldive, India and Pakistan.

The group consisting of mackerels, billfishes, etc. account for 8·56 per cent of the total landings. Out of an average catch of 1,83,000 tonnes, India lands on an average 83,000 tonnes, Malaysia 11,000 tonnes, Pakistan 11,000 tonnes and Indonesia 27,000 tonnes. The average composition of the landings in India is Ribbon fish, 40,000 tonnes; Indian mackerel, 33,000 tonnes; seer fish, 10,000 tonnes.

## POTENTIAL YIELD (ASSESSED FROM EXPLORATORY SURVEYS)

*East African coast (inshore waters)*

The maximum sustainable yield from the inshore areas is believed to be small. There are indications that catches from the coastal fisheries of the islands are already reaching or have reached their maximum. Wheeler and Ommanney (1953) regarded the Mauritius inshore fishery as "a closed fishery, confined with unalterable limits and incapable of yielding more than a certain amount of fish, however intensively fished." Likewise, in the Seychelles inshore fishery "there is reason to believe that overfishing of a limited stock has already taken place" (Anon., 1965). According to Moal (1962) the physical features of the coastal shelf limits the development of coastal fishery of Comoro Islands. In Madagascar the broader shelf of the west coast has development potential. Kerr (1966) estimated a 50 per cent increase in production as the maximum possible attainable limit, though according to Shomura *et al.* (1967) a five-fold or more increase is possible. Selwyn and Watson (1962) reported on the great scope for development output of fish from Zanzibar Island. Considering other evidences, Kerr (1966) concluded that fishable resources of Tanzania, as a whole, are not more than 50 per cent higher than the present catch of the two former constituent countries. Rhodes (1966) remarked that the present catch of Kenya cannot be increased beyond 20,000 tonnes. According to Sanchez (1960) the production along Mozambique coast could be doubled or trebled by improving the present fishing methods and research. Considering the various view points, the potential yield from inshore coastal fishery of East African coast has been derived (Table 4).

TABLE 4. POTENTIAL YIELD FROM THE EAST AFRICAN COASTAL FISHERY

| Coast | Present catch (in 1,000 tonnes) | Potential catch (in 1,000 tonnes) |
|---|---|---|
| South Africa | 3·0 | 6·0 |
| Mozambique | 5·8 | 17·4 |
| Tanzania | | |
| Tanganyika | 16·8 | 40·4 |
| Zanzibar | 10·1 | |
| Kenya | 6·2 | 20·0 |
| Mauritius | 1·4 | 1·4 |
| Madagascar | 9·8 | 14·7 |
| Reunion Islands | 2·5 | 2·5 |
| Comoro Island | 1·6 | 1·6 |
| Seychelles | 1·5 | 1·5 |
| | 58·7 | 105·5 |

*Demersal fishery of the offshore banks*

There are several large areas of shallow banks in the western Indian Ocean, particularly on an area between Seychelles and Mauritius, also to the north-west of Madagascar (Aldabra Islands) and to the east, almost in the middle of the Indian Ocean (Chagos Archipelago). These areas are largely unfished. They were, however, surveyed in 1948 and 1949 and it was concluded by Wheeler and Ommanney (1953) that there are very large areas where fishing by the simple method of hand-lining is productive on a scale equalling the best efforts of trawlers and drifters on some of the richest grounds in the world. The availability is almost constant throughout the year and the main demersal fish like *Lutianus civis* and *Lethrinus* can be obtained. Rough calculation showed that available fish potential including sharks is between 2 and 3 million tonnes. Kerr (1966), however, is very skeptical if this high reserve can be exploited at present, though he admits that the resource does represent a large reserve of fish for the subregion, and if fishing technology develops enabling its economic exploitation it may be possible eventually to utilize it.

*Sardinella fishery*

Substantial stock of *Sardinella* exists in Zanzibar and Pemba channels. *S. jussius* and *S. perforata* frequent inshore waters, but *S. sirm* is present only in small numbers in inshore waters. Losse (1963) felt that large quantities of *S. sirm* can be found further out in sea. Only a small quantity is available in other coastal waters. In Kenya not more than 300 tonnes could be caught (Bell and Ochi, 1965). According to Kerr (1966), a potential catch of 5,000 tonnes on present assessment could be expected.

*Crustacean fishery*

Postel (1965) estimated that the resources of lobster along the East African coast could yield about 5 times their present yield, but no increase is possible from Madagascar stock, which is limited. The total lobster catch could therefore be increased to 3,000 tonnes in the area.

Kerr (1967) concluded that for prawns the maximum sustainable yield for the region would be about 10,000 tonnes.

The break-up of the total potential yield for the area is 31,25,000 tonnes. The break-up (in thousand tonnes) is as follows: Inshore, 105; Banks 3,000; *Sardinella* 5; Crustacea 15.

*Arabian Sea coast*

*French Somaliland and Somalia:* The shelf in French Somaliland and Somalia is narrow. The resources here are mainly pelagic. The potential yield from these coastal waters will be about 50 per cent more than the present catch, i.e. about 8,000 tonnes (Kerr, 1966).

*South Arabian Peninsula:* According to Morgan (1966) there is some scope for increased catches of ground fish if suitable gear can be devised to meet the often difficult bottom conditions of the continental shelf off the south Arabian Peninsula, where the shelf averages no more than 8 km in width. Mietle (1967) remarked that the sea of the south Arabian Peninsula could yield annually twice the quantity landed at present, i.e. 70,000 to 1,00,000 tonnes.

Even though there is limited scope for development of demersal fisheries, there are possibilities of significant development of pelagic fisheries in this region. This area is very rich in nutrient salts and plankton due to seasonal upwelling of deep water during the south-west monsoon. According to Schaefer (*vide* Shomura *et al.*, 1967) this area can support a production as high as 10 million tonnes. According to Mietle (1967), the maximum sustainable yield of pelagic fish in the Gulf of Aden is at least 1,50,000 tonnes, consisting of 15,000 to 20,000 tonnes of tuna, 70,000 to 80,000 tonnes of sardines, 20,000 tonnes of king fish and 30,000 tonnes of Indian mackerel. The greatest potentiality for development, however, seems to be in the eastern part of the south Arabian coast and in the Gulf of Oman, an area which could support a sustainable annual yield of about 5,00,000 tonnes of pelagic fish (Kerr, 1966). According to a survey report of FAO/EPTA (Anon., 1963) there does not seem to be much of shrimp resource in the area, but the area can probably support an annual yield of a few thousand tonnes of lobsters.

Thus the potential yield of all types of fishes from this area would seem to be about 7,50,000 tonnes.

*West Pakistan:* The present yield from the waters off West Pakistan is about 1,17,000 tonnes, of which about 84,000 tonnes are demersal fish. Tiews (1966) estimated a potential yield of about 2,10,000 tonnes of demersal fish from the shelf area of West Pakistan. Jones and Banerji (1968) showed that the same area could probably support an annual yield of 1,63,000 tonnes of demersal fish, i.e. about 30 kg per hectare of water surface area. A potential yield of about 90,000 tonnes of pelagic fish could be taken off annually from the shelf area.

*West Coast of India:* Jones and Banerji (1968) observed that the shelf area could support an annual yield of 5,77,000 tonnes of demersal fish including crustaceans and about 10,20,000 tonnes of pelagic fish. The present average annual yield from the shelf area is about 6,50,000 tonnes consisting of 1,80,000 tonnes of demersal and 4,70,000 tonnes of pelagic fish.

*Laccadive and Maldive Islands:* There are also possibilities of development of pelagic fisheries in the shelf area off these islands. The total catch at present is of the order of 16,000 tonnes, mainly in pelagic fish. Jones and Banerji (1968) stated that an annual catch of 7,000 tonnes of demersal and 22,000 tonnes of pelagic fish could be harvested from the shelf areas of these island groups. The estimated total potential annual yield from the Arabian Sea area is given in Table 5.

TABLE 5. POTENTIAL ANNUAL YIELD FROM THE ARABIAN SEA AREA

| | Demersal (including crustaceans) | Pelagic | Total |
|---|---|---|---|
| French Somaliland and Somalia | — | — | 8,000 |
| Federation of South Arabia, Muscat, Oman | 1,00,000 | 6,50,000 | 7,50,000 |
| West Pakistan | 1,60,000 | 90,000 | 2,50,000 |
| India, west coast | 5,80,000 | 10,20,000 | 16,00,000 |
| Maldives, Laccadives, Chagos, St Paul and New Amsterdam | 7,000 | 23,000 | 30,000 |
| Total | 8,47,000 | 17,83,000 | 26,38,000 |

*Red Sea*

The present landings in this area are of the order of 44,000 tonnes, pelagic species forming the bulk.

The Red Sea is an almost land-locked basin and the fauna of the basin is likely to be either completely or partially isolated. Hence, apart from some pelagic species, the fish stock should be regarded as self-supporting and as such there is not much scope for development of demersal fishery. However, there seems to be susbstantial scope for development of pelagic fisheries. Nelson and Lee (1962) observed schools of fish of tremendous size in the central and southern parts of the Red Sea. The Greek fishermen who visited these regions have given the pontential catch of 1,40,000 tonnes per month from the Red Sea. The findings of *Atlantis II* of the Woods Hole Oceanographic Institute also support the richness of the Red Sea in fish fauna. But it is also possible that only limited areas of Red Sea, particularly in the south, are rich in fish fauna (Anon., 1962). Nelson and Lee (1962) in their survey of Egyptian waters pointed out that the catch does not seem to be very great in the northern part of the Red Sea, including Gulf of Suez. According to them, there is some evidence that the resources may be over-exploited. There seems to be some potential oyster resources in Gulf of Suez area.

The fishing ground near Port Sudan, where most of the fishing has so far been carried out, does not seem to be productive (Anon., 1958). The best grounds are found outside and near the islands and reefs up to a distance of 60 miles from Port Sudan. Kristjonsson (1956, 1958) observed that, except for some red snappers in some seasons, there is no evidence of abudance of fish in southern Sudan. Reed (1964) found that there are no opportunities for the development of large-scale commercial fisheries in Sudan and the present annual Sudanese catch can at best be increased only to about 3,000 tonnes.

There appear to be some possibilities for increasing the fish catch along Saudi Arabian coast. Exploratory fishing in Saudi Arabian coast indicated the presence of schools of pelagic fish, mainly bonito, and also mackerel and sardines (Anon., 1958). Some relatively productive trawl grounds were also found, but the catch consisted of small fish which are not in great demand. No estimates are, however, available of the potential annual yield from the Saudi Arabian coast.

An excellent shark fishery is now being developed near Karaman Island. There are also reports that Yemen has considerable potential for developing its Red Sea fisheries resources.

Mietle (1967) concluded that the Red Sea as a whole can yield about 1,50,000 tonnes of fish annually, i.e. about 3 times the present yield. According to him the major part would consist of pelagic species such as sardines, tuna, mackerel and sharks. He also assumed that crustacean stocks would yield a few thousand tonnes.

*Persian Gulf*

This gulf is a shallow basin with a mean depth of about 35 m and a maximum depth of about 150 m. The bottom is of sand and soft mud; the southern part is interspersed with numerous coral reefs. Extensive trawlable grounds exist, particularly near the Iranian coast.

The average annual catch based on 1965–67 data is estimated at about 48,000 tonnes consisting of about 18,000 tonnes of demersal fish, 18,000 tonnes of pelagic and about 12,000 tonnes of shrimps.

Mietle (1967), while discussing the potential yield from the Persian Gulf, concluded that about 30,000 tonnes of demersal fish, 40,000 tonnes of pelagic fish and 25,000 tonnes of crustaceans, totalling 95,000 tonnes, could be obtained as sustained annual yield from the area.

Thus for the western Indian Ocean, excluding the oceanic resources, the annual potential yield would be about 6 million tonnes (Table 6).

TABLE 6. ANNUAL POTENTIAL YIELD FROM THE WESTERN INDIAN OCEAN (IN 1,000 TONNES)

| Coast | Demersal | Pelagic | Crustacean | Total |
|---|---|---|---|---|
| East African coast | 105 | 5 | 15 | 125 |
| East African Offshore Bank | 3,000 | — | — | 3,000 |
| Arabian Sea | 650 | 1,790 | 200 | 2,640 |
| Red Sea | 120 | 25 | 5 | 150 |
| Persian Gulf | 30 | 40 | 25 | 95 |
| Total | 3,905 | 1,860 | 245 | 6,010 |

*Bay of Bengal*

*East coast of India:* The present average annual production from the east coast of India is about 65,600 tonnes of demersal fish and 1,47,000 tonnes of pelagic fish. Proper exploitation of the shelf area beyond the currently exploited fishing grounds is, however, likely to open up new unexploited grounds of demersal fish. Jones and Banerji (1968) estimated a potential yield of 1,43,000 tonnes of demersal and 6,72,000 tonnes of pelagic fish from the shelf area of the east coast of India.

*East Pakistan:* East Pakistan has a wide shelf area enriched by the silt-laden discharge of the Ganges river system. The shelf area is practically unexploited at present. Some demersal fish are caught near the inshore waters. Tiews (1966) estimated a potential annual catch of 1,20,000 tonnes of demersal fish from the shelf area of East Pakistan, whereas according to the estimate of Jones and Banerji (1968) the potential annual yield of demersal fish would be 98,000 tonnes and that of pelagic fish 2,50,000 tonnes from the shelf area of East Pakistan.

*Burma:* The present catch of demersal fish is only 5 kg per hectare of the shelf area. Tiews (1966) estimated a pontetial yield of 3,70,000 tonnes of demersal fish. There are also great potentialities for pelagic fish. Jones and Banerji (1968) estimated a potential annual yield of 7,26,000 tonnes of fish from the shelf area of Burma, consisting of 3,26,000 tonnes of demersal fish and 4,00,000 tonnes of pelagic fish.

*West coast of Thailand:* The west coast of Thailand has a wide shelf area, the width of the shelf being 64 to 160 km wide. The present catch is only 23,900 tonnes, consisting of about 5,000 tonnes of *Rastrelliger* spp., 8,600 tonnes of sharks and rays, 1,000 tonnes of crustaceans, and the balance in miscellaneous fish. The low production is because the west coast of Thailand is exploited very little at present. Tiews (1966) estimated that this area could support an annual potential yield of about 56,000

*Indonesia and Australia*

*West coast of Indonesia:* Shomura *et al.* (1967) assessed the annual production of marine fish in 1963 from west coast of Indonesia at about 1,15,000 tonnes. Taking the average annual total fish production based on figures of 1965 and 1966 (Anon., 1967) and substracting the average freshwater fish production and taking 25 per cent of that to be production from the west coast of Indonesia, the present estimated production is of the order of 1,75,000 tonnes. No information is available on the composition of the catch, but according to Shomura *et al.* (1967) the fishery resources are similar to that of North Australia, Malaysia, Thailand and Burma. Although estimates of potential annual yield are not available, this area is very rich and upwellings are found south of Sunda Islands. Hence, it may be assumed that the potential yield would be at last two times the present yield, i.e. 3,50,000 tonnes. The only area suitable for trawling lies off the western end of Sumatra. The potential for the greatest increase in yield probably lies in the area along the southern coast of Java, where intense upwelling occurs. There is a fishery for sardines in the Straits east of Java. The catch from this area may be from the fringe of a large sardine resource of the south. If the conditions are similar to other areas of upwelling in the Indian Ocean, a large resource of clupeoids could be expected.

*West Australia:* The continental shelf is less than 65 km in width in the south-western part of the continent. Northwards the shelf becomes wider, and in the north-west it exceeds 320 km in width. The present annual yield is about 12,000 tonnes including about 7,500 tonnes of crayfish. The Australian scientists estimated that the optimum yield of crayfish in the west Australian stock to be about $7 \cdot 3 \pm 0 \cdot 9$ thousand tonnes. Hence, no further increase in crayfish landings seems possible. But possibilities of development exist in the north-western coast of Australia with a very wide trawlable shelf. The area is very poorly known. Recent surveys show that potential for prawns is good. Substantial catches of bottom fishes of good quality were made during a Japanese bottom trawling survey (Masuda *et al.*, 1964). These indicate prospects of increasing the present meagre yield of 12,000 tonnes and with the present knowledge of the area of potential yield of 50,000 tonnes does not seem to be an unreasonable estimate.

The area-wise break-up of the potential annual yield for the eastern Indian Ocean is given in Table 8.

TABLE 8. POTENTIAL ANNUAL YIELD FOR THE EASTERN INDIAN OCEAN (IN 1,000 TONNES)

| | Demersal | Pelagic | Total |
|---|---|---|---|
| Bay of Bengal | 1,281 | 1,540 | 2,821 |
| Indonesia | 90 | 260 | 350 |
| Australia | 30 | 20 | 50 |
| Total | 1,401 | 1,820 | 3,221 |

*Oceanic fishery:* The oceanic fishery consists of various types of tunas and bill-fishes. The estimated catch taken from the Indian Ocean is about 1,50,000 tonnes, comprising yellowfin tuna, big-eyed tuna, albacore, bluefin tuna, marlins, skipjacks and sauries.

The yellowfin tuna has a wide distribution but the maximum concentration is in the equatorial waters. The fish is virtually absent in the northern portions of Arabian Sea and Bay of Bengal. According to Mimura (1958) the average size of yellowfin tuna taken by long-line has decreased since the commencement of the fishery. Hayashi (1966) came to the conclusion that the present fishing intensity may be very near the maximum level that could be employed for getting an optimum yield of this species.

Big-eyed tuna, distributed almost throughout the Indian Ocean, are mostly concentrated between the equator and 10°S Lat. in the eastern Indian Ocean and between equator and 10°N Lat. in the western Indian Ocean. Like the yellowfin, the species is again absent in the northern portions of Arabian Sea and Bay of Bengal. Suda (1966) remarked that the coefficient of natural mortality $M$ is 0·6 and that of fishing mortality $F$ varies from 0·3 to 0·6. The maximum sustainable yield would be achieved according to him at $F$=0·7. Sakamoto (1966) by analysing catch and effort data came to the conclusion that the big-eyed tuna population has somewhat declined in the Indian Ocean.

The greatest concentration of albacore is in the south-west region of the Indian Ocean, though the species is available throughout the Indian Ocean south of the equator, it being practically absent north of the equator. The relative abundance of albacore has gradually decreased since 1953, and in 1963 it was about half that of the earlier years.

The bluefin tuna has a scattered distribution south of the equator. It is highly abundant in the south of Indonesia and in the north-west, west and south-west of Australia. It is also fairly abundant off South Africa during southern winter (Talbot and Penrith, 1963). The Australian catch of bluefin tuna has increased considerably, primarily due to increase in Australian pole-and-line fishery. The relative abundance has declined to about one-third that of earlier years. According to Hynd *et al.* (1966), the total catch of bluefin tuna represents about 10 per cent of the population off South Australia.

Excepting the northern portions of Arabian Sea and Bay of Bengal, marlins are available throughout the Indian Ocean. Striped marlins are abundant in the Bay of Bengal and south-west coast of India, and blue marlins in greatest abundance in south of regions of abundance of striped marlin. The highest concentration of black marlins are in the eastern Indian Ocean—west of Indonesia and north-west Australia. Changes in abundance have not been computed.

The skipjack tuna is exploited very little at present. The main fisheries at present are the pole-and-line fishery of Minicoy and the small trolling fishery of Ceylon. According to Chapman (1962) there is no reason to suspect that they are not so abundant in the Indian Ocean as compared to the Pacific. The meagre production of skipjack at present is becaue they are not caught. Its yield from the Indian Ocean can be increased many-fold from its present estimated catch of 5,000 tonnes.

Similarly, Saury is encountered throughout the wide area of the southern Indian Ocean. Saury might also represent a large latent resource.

The assessment made by Shomura *et al.* (1967) showed that, although a number of tuna species in the Indian Ocean are being taken by long-line gear at levels which suggest little or no potential increase, the skipjack tuna and Saury are very much under-utilized resources.

In terms of production per unit area of water, the yield from the Indian Ocean is about a third of that from the Pacific Ocean, where maximum exploitation has not yet been attained. It is therefore reasonable to assume that the Indian Ocean can be exploited at least to the level of present-day fishing in the Pacific Ocean to give an annual yield of 4,50,000 tonnes of oceanic pelagic fish like tunas.

Thus, combining the various estimates of potential yield available from different regions based on exploratory surveys and various other considerations, it is seen that the Indian Ocean can probably support an annual potential yield of 10–11 million tonnes of marine fish.

## COMPOSITION OF POTENTIAL INCREASE

The total catch from the western Indian Ocean at present is about 10,91,400 tonnes. The potential yield from the area was computed at 60,10,000 tonnes consisting of about 39,05,000 tonnes of demersal fish, 2,45,000 tonnes of crustaceans and 18,60,000 tonnes of pelagic fish. The potential increase possible is thus about 49,20,000 tonnes per year. The regional distribution of this is shown in Table 9.

TABLE 9. REGIONAL DISTRIBUTION OF POTENTIAL INCREASE IN WESTERN INDIAN OCEAN (IN 1,000 TONNES)

| Region | Demersal (including crustaceans) | Pelagic | Total |
|---|---|---|---|
| Red Sea | 10 | 90 | 100 |
| African coast | 25 | 40 | 65 |
| Offshore banks of Africa | 3,000 | — | 3,000 |
| Arabian Sea | 533 | 1,175 | 1,708 |
| Persian Gulf | 25 | 22 | 47 |
| Total | 3,593 | 1,327 | 4,920 |

According to Mietle (1967) the potential annual yield from the Red Sea area will be about 1,50,000 tonnes as against the present annual catch of 45,000 tonnes. The composition of the potential increase (in tonnes) will be: Sardines, 20,000; mackerel, 25,000; tuna and bonitos, 40,000; sharks, 5,000; perches, 5,000; crustaceans 5,000 and other species 5,000.

The flatfish stocks of the Agulhas Bank are probably being exploited to the maximum. But the fisheries of pilchard (*Sardinops*) and rocky bottom fishes of the shelf of South Africa could be developed further. Similarly, the *Sardinella* and other coastal pelagic fisheries could be developed off the coasts of Mozambique, Tanzania and Kenya. The outlook of development for prawn and lobster fisheries along these coasts is also bright. The development of north-west coast fisheries of Madagascar is likely to fetch increased yield of *Sardinella* and associated species. Exploitation of offshore regions of Zanzibar and East Africa might yield additional quantities of crustaceans and *Sardinella sirm*. The increased yield from these development measures might yield 40,000 tonnes pilchard and sardines and 25,000 tonnes crustaceans. But the maximum potential yield might come from exploitation of the offshore banks between Seychelles and Mauritius, and would consist of fishes like *Lutiannus civis*, *Lethrinus* and sharks.

The Arabian Sea could also support a potential increase of 17,08,000 tonnes of fish above its present annual yield. The shelf area of South Arabian Peninsula and Oman could yield an additional 50,000 tonnes of ground fish and 5,50,000 tonnes of pelagic fish, the likely composition of which (in tonnes) would be: tuna, 60,000; sardines, 3,10,000; kingfish, 60,000; and mackerel, 1,20,000.

Tiews (1966) and Jones and Banerji (1968) observed that the major resources of bottom fish on the coasts of West Pakistan and west coast of India remain virtually untapped. According to the latter the commercial exploitation of the shelf area of this region could yield an additional quantity of nearly 4,75,000 tonnes of demersal fish including shrimps and lobsters. Although it is difficult to give a detailed composition of this additional yield, some idea could be obtained from the exploratory fishing carried out in India. According to Jones and Banerji (1968) the demersal catch from the Maharashtra and Gujarat area consisted of elasmobranchs, eels, catfishes, perches, red mullets, polynemids, sciaenids, *Lactarius*, pomfrets, soles, prawns and other miscellaneous catch. The catch as well as catch per unit effort from both inshore and offshore fisheries definitely declined in case of *Polynemus indicus* (*dara*), *Otolithoides brunnes* (*koth*) and eels. In case of most other groups, no such declining trends were noticed, suggesting that most of these demersal species were under-exploited. Though, in general, the catch rate declined beyond 40 m in case of certain categories of fish like small sciaenids, eels and elasmobranchs, the catch rate increased beyond 40 m belt and these areas remain practically unfished at present. In the shelf area of Mysore and Goa no special effort was made to fish for demersal fishes, the fishing at present being restricted to coastal waters. Only recently a few small motorized boats have started operating for the exploitation of prawns. Exploratory shrimp trawling done in Karwar has showed excellent catch rate of 192 kg per hour. Very little prawns were obtained. *Opisthopterus tardoore* and *Leiognathus* formed more than 50 per cent of the catches along with sizable catch of *Lactarius*, sciaenids and elasmobranchs. Since none of these species are now being exploited to any degree in the coastal waters at present, they form potential resources to be exploited. The shelf area of Kerala is being exploited up to 40–50 m. The main groups of fish are prawns, elasmobranchs, catfishes, sciaenids, sole and other miscellaneous fish. Prawns form about 45 per cent of the demersal catch. The catch per unit effort and the mean size of prawn in the commercial catch show decline, and the catch also do not show noticeable increase. It probably indicates that the prawn stocks within the 50 m belt are being exploited to the maximum. The other groups seem to be very much under-exploited. Further, the area between 50 and 200 m remains practically unexploited. Recently, some new prawn and lobster beds have been discovered in the deep water with promising prospects. Rao (1969) gave detailed account of the results of exploratory surveys in the shelf area of India.

The present yield of pelagic fisheries from the shelf area of west coast of India is about 4,70,000 tonnes. Oil sardine, Bombay duck and mackerel form about 70 per cent of the total pelagic catch. The fisheries of oil sardine and mackerel are characterized by their wide annual fluctuations. The prevailing view is that these fluctuations are caused by variations in availability of the stocks due to the severely restricted fishing range at present. The annual catch of Bombay duck has declined somewhat during the last decade. The fishing is by fixed bag net, and hence it is possible that the catch depends on availability. The species is neritic-pelagic having a long migration circuit still unknown. Hence it is likely that the present catch of all these three species is much lower than the potential yield. The stocks of other small pelagic groups are not exploited to the full and some potential increase from these stocks seems possible.

The total catch from the eastern Indian Ocean at present is about 8,95,000 tonnes and the potential yield has been estimated in the preceding section at 32,21,000 tonnes consisting of 14,00,000 tonnes of demersal fish and 18,20,000 tonnes of pelagic fish. The region-wise break-up of the potential increase is given in Table 10.

TABLE 10. REGIONAL DISTRIBUTION OF POTENTIAL INCREASE (EASTERN INDIAN OCEAN) (IN 1,000 TONNES)

| Region | Demersal (including crustaceans) | Pelagic | Total |
|---|---|---|---|
| India (east coast) | 77 | 525 | 602 |
| East Pakistan | 62 | 238 | 300 |
| Burma | 198 | 272 | 470 |
| Thailand (west coast) | 43 | 11 | 54 |
| Malaysia (west coast) | 560 | 70 | 630 |
| Ceylon | 18 | 27 | 45 |
| Andaman and Nicobar Islands | 4 | 8 | 12 |
| Indonesia (east coast) | 45 | 130 | 175 |
| Australia (west coast) | 22 | 16 | 38 |
| Total | 1,029 | 1,297 | 2,326 |

At present, along the east coast of India the demersal fishery is exploited in inshore waters with shore-seines and boat-seines. Experimental fishing done at Tuticorin, Mandapam and Waltair shows good catch rates, though not as high as in the west coast. Experimental fishing off Tuticorin in south-east India showed that sciaenids, *Leiognathus*, elasmobranchs, prawns, perches, polynemids and miscellaneous fishes form the demersal fishery. Exploratory fishing around Mandapam showed that the catch consisted of about 90 per cent of *Leiognathus*, the rest being *Lactarius*, prawns, pomfrets, catfish and sharks. The catch obtained from exploratory fishing around Waltair composed of elasmobranchs, catfishes and others.

The wide shelf area of East Pakistan, Burma, Thailand and Malaysia would yield a substantial amount of demersal fish, the composition of which is difficult to predict. The only areas which are shallow enough for trawling occur off the western end of Sumatra, the north-west coast of Australia and some sections of southern coast of west Australia.

The pelagic resources of the Bay of Bengal might consist of fishes like mackerel, *Decapterus*, *Stolephorus*, wolf herrings and lesser sardines. The stock of each of these might not be large but there might be a large number of small stocks of many species.

According to Shomura *et al.* (1967) mussel and fish farming have tremendous possibilities in the delta area of Bay of Bengal and other mangrove estuarine areas of Burma, Thailand and Malaysia.

## ESTIMATION OF POTENTIAL YIELD FROM VARIOUS TROPHIC LEVELS

Schaefer (1965) estimated the potential productivity of the sea by calculating the harvestable crop from the net rate of photosynthesis of organic matter and its subsequent transfer through the food web. The input of any trophic level is taken as the predation loss from the next lower trophic level. By taking a suitable ecological efficiency factor, the maximum sustainable rate of yield (predation loss) from a trophic level is obtained. According to Schaefer (1965) "the effective ecological efficiency may be higher than 10 per cent due to recycling of organic matter, 15 per cent would not seem an unreasonable guess and 20 per cent should be possible". It is not always possible to assign a proper trophic level to many organisms. Pelagic fishes like sardines, anchovies and herring which feed on phytoplankton and a mixture of phyto- and zooplankton are considered as one and a half steps above phytoplankton, while the other types of fishes especially tunas are taken from higher trophic levels. The carbon production of the western and eastern Indian Ocean has been separately traced through the various trophic levels (Tables 11, 12).

TABLE 11. ESTIMATES OF POTENTIAL YIELDS AT VARIOUS TROPHIC LEVELS (ANNUAL), WESTERN INDIAN OCEAN

| Trophic level | Ecological efficiency factor | | | | | |
|---|---|---|---|---|---|---|
| | 10% | | 15% | | 20% | |
| | Carbon | Total wt. | Carbon | Total wt. | Carbon | Total wt. |
| (0) Phytoplankton (net production) | $2{\cdot}3 \times 10^9$ | — | $2{\cdot}3 \times 10^9$ | — | $2{\cdot}3 \times 10^9$ | — |
| (1) Herbivores | $2{\cdot}3 \times 10^8$ | $2{\cdot}3 \times 10^9$ | $3{\cdot}3 \times 10^8$ | $3{\cdot}3 \times 10^9$ | $4{\cdot}6 \times 10^8$ | $4{\cdot}6 \times 10^9$ |
| (2) 1st stage carnivores | $2{\cdot}3 \times 10^7$ | $2{\cdot}3 \times 10^8$ | $5{\cdot}0 \times 10^7$ | $5{\cdot}0 \times 10^8$ | $9{\cdot}2 \times 10^7$ | $9{\cdot}2 \times 10^8$ |
| (3) 2nd stage carnivores | $2{\cdot}3 \times 10^6$ | $2{\cdot}3 \times 10^7$ | $7{\cdot}4 \times 10^6$ | $7{\cdot}4 \times 10^7$ | $17{\cdot}6 \times 10^6$ | $17{\cdot}6 \times 10^7$ |
| (4) 3rd stage carnivores | $2{\cdot}3 \times 10^5$ | $2{\cdot}3 \times 10^6$ | $11{\cdot} \times 10^5$ | $11 \times 10^6$ | $35{\cdot}2 \times 10^5$ | $35{\cdot}2 \times 10^6$ |

TABLE 12. ESTIMATES OF POTENTIAL YIELDS AT VARIOUS TROPHIC LEVELS (ANNUAL), EASTERN INDIAN OCEAN

| Trophic level | Ecological efficiency factor | | | | | |
|---|---|---|---|---|---|---|
| | 10% | | 15% | | 20% | |
| | Carbon | Total wt. | Carbon | Total wt. | Carbon | Total wt. |
| (0) Phytoplankton (net production) | $1 \cdot 6 \times 10^9$ | — | $1 \cdot 6 \times 10^9$ | — | $1 \cdot 6 \times 10^9$ | — |
| (1) Herbivores | $1 \cdot 6 \times 10^8$ | $1 \cdot 6 \times 10^9$ | $2 \cdot 4 \times 10^8$ | $2 \cdot 4 \times 10^9$ | $3 \cdot 2 \times 10^8$ | $3 \cdot 2 \times 10^9$ |
| (2) 1st stage carnivores | $1 \cdot 6 \times 10^7$ | $1 \cdot 6 \times 10^8$ | $3 \cdot 6 \times 10^7$ | $3 \cdot 6 \times 10^8$ | $6 \cdot 4 \times 10^7$ | $6 \cdot 4 \times 10^8$ |
| (3) 2nd stage carnivores | $1 \cdot 6 \times 10^6$ | $1 \cdot 6 \times 10^7$ | $5 \cdot 4 \times 10^6$ | $5 \cdot 4 \times 10^7$ | $12 \cdot 8 \times 10^6$ | $12 \cdot 8 \times 10^7$ |
| (4) 3rd stage carnivores | $1 \cdot 6 \times 10^5$ | $1 \cdot 6 \times 10^6$ | $8 \cdot 1 \times 10^5$ | $8 \cdot 1 \times 10^6$ | $25 \cdot 4 \times 10^5$ | $25 \cdot 4 \times 10^6$ |

It may be seen that if the harvest is taken at step 3 with 10 per cent efficiency, the potential biomass of fish is 23 millon tonnes from the western half and 15 million tonnes from the eastern half. At 15 per cent efficiency the corresponding biomass will be 74 and 54 millions, respectively. If it is assumed that half of the potential is taken at step 2 and half at 3, the figures will be (126+88 million) and (287+207 million), respectively, at 10 and 15 per cent efficiencies for the whole of the Indian Ocean.

ZOOPLANKTON BIOMASS AND POTENTIAL YIELD IN THE INDIAN OCEAN

The zooplankton biomass distribution in the Indian Ocean is shown in Fig. 2. Prasad (1969) observed that the average annual distribution of plankton biomass in the Arabian Sea had the same pattern of distribution as during the south-west monsoon period with the maximum concentration in the western half. The highly productive areas were found around the Somali and Arabian coasts and to a certain extent on the south-western coast of India. The low-productivity zones occupied the central part of the Arabian Sea. For the Bay of Bengal there was no distinct variation between the two monsoon periods or for the entire IIOE period. The distribution was comparatively sparse and the biomass was lower. The southern hemisphere, especially south of 10°S latitude, exhibited a very low zooplankton biomass, whereas the regions south of the Indonesian Archipelago and the western coast of Australia showed a higher density of plankton. Taking all these zooplankton biomass data into consideration, estimates of the total biomass for the western and the eastern halves of the Indian Ocean have been made. The general distribution and regional variation in primary production agreed well with the pattern of zooplankton distribution for the two sectors of the Indian Ocean. Since these estimates are based on uneven number of samples collected in different times in each 5° square, they may be considered as approximate averages. The estimated biomass for the western half is computed at $3 \cdot 25 \times 10^8$ tonnes and for the eastern half at $1 \cdot 94 \times 10^8$ tonnes. The theoretical estimates from carbon production are $2 \cdot 3 \times 10^9$ and $1 \cdot 6 \times 10^9$ tonnes at

10 per cent efficiency and $3 \cdot 3 \times 10^9$ and $2 \cdot 4 \times 10^9$ tonnes at 15 per cent efficiency for the two halves, respectively. This estimate is for plankton composed purely of herbivores. Since the zooplankton is composed of herbivores and first-stage carnivores, the estimates of biomass based on zooplankton data would definitely be of lower order of magnitude than the theoretical estimates derived from carbon production.

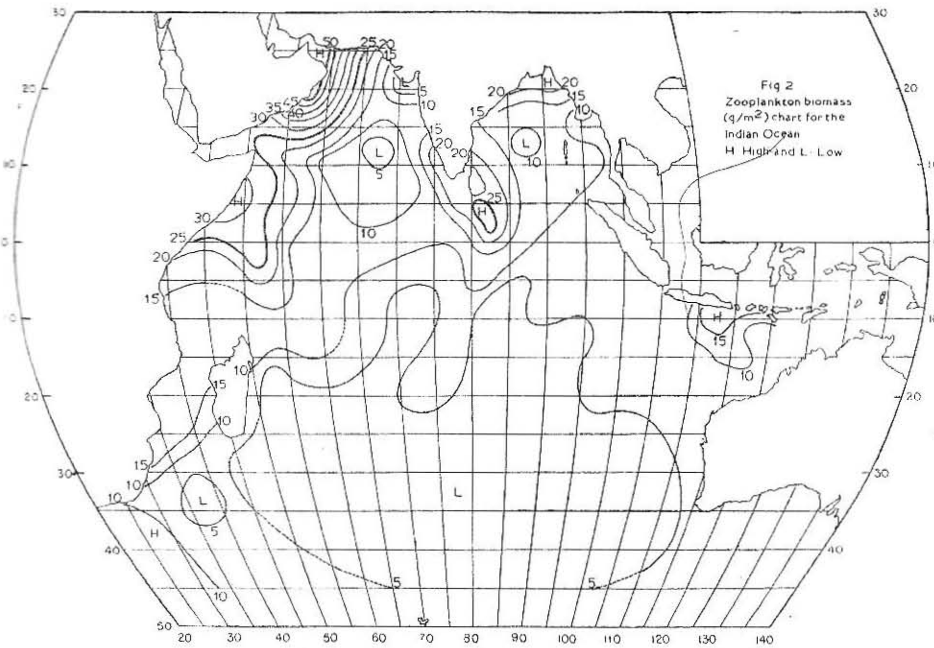


Fig. 2.

The potential fish biomass based on the estimated zooplankton biomass is computed at 18 million tonnes from the western half and 11 million tonnes from the eastern half at 10 per cent efficiency. At 15 per cent efficiency the estimates would be 28 million from the western half and 17 million tonnes from the eastern half. These estimates of fish biomass are also likely to be underestimates, since they are based on samples taken mostly from oceanic regions during the IIOE.

## CONCLUSIONS

The relative productivity in the Indian Ocean as a whole is in no way less than that of the rest of the world oceans. At the same time pockets of high productivity occur with rates higher than anywhere else in the world. With an annual organic net production of $3 \cdot 9 \times 10^9$ tonnes for an area of $51 \times 10^6$ sq km, it is approximately one-fifth of the world oceanic production, which is estimted at $1 \cdot 9 \times 10^{10}$ tonnes. The Indian Ocean should therefore logically account for one-fifth of the world production of fish also, provided other conditions are favourable. A perusal of the yield raito of the present catch of fish from the Indian Ocean and the Atlantic and Pacific Oceans reveals that the rate for the Indian Ocean is only 0·005 per cent while that of the Atlantic is 0·04 per cent and Pacific 0·03 per cent. Accordingly, the possible catch should be of the order of 11 to 12 million tonnes at the present level of world fishing to bring it at par with the rest of the world oceans. The results of exploratory surveys and the estimate of the potential catch also show that the Indian Ocean can possibly provide an annual yield of 10–11 millon tonnes of fish.

In most of the countries bordering the Indian Ocean, the technological development has not yet attained the stage to provide the facilities for fishing in distant waters. Hence the maximum utilization of the resources available on the continental shelves and banks should form the mainstay at the present stage. From the rates of organic productivity observed in the coastal and near-shore regions, the annual net production is found to be of the order of $560 \times 10^6$ tonnes of carbon for an area of 3·1 million sq km. In eutrophic coastal areas where 0·2 to 0·3 per cent of the carbon is taken as fish, a possible yield of 11 million tonnes could be taken if the resources are fully utilized. This excludes the oceanic fisheries consisting of tunas, billfishes, etc., the present yield of which is about 1,50,000 tonnes. In terms of production per unit area of water the yield from the Indian Ocean from these resources is only a third from that of the Pacific Ocean, where itself the maximum exploitation has not yet been attained.

The theoretical estimates using the method followed by Schaefer (1965) puts the fish biomass for the entire Indian Ocean at 10 per cent efficiency at 39 million tonnes, and at 15 per cent efficiency at 128 million tonnes if the harvest is taken at step 3. If it is assumed that half the harvest is taken at step 2 and half at step 3, the biomass will be 214 and 494 million tonnes at 10 and 15 per cent efficiencies, respectively. Schaefer's estimates of fish biomass at 15 per cent efficiency for the world oceans are $640 \times 10^6$ tonnes if the harvest is taken at step 3, and $2{,}420 \times 10^6$ tonnes if half the harvest is taken at step 2 and half at step 3. According to him, about 200 million tonnes can be taken as the potential yield, i.e. 30 per cent of the former or about 8 per cent of the latter estimates of fish biomass, due to diffuse distribution of fish, economic inability to harvest and loss through predators. Thus, for the Indian Ocean the potential yield derived from the present estimates would be between 39 and 40 million tonnes. However, at the present level of world exploitation, which is only about 27 per cent of the projected potential yield of 200 million tonnes, the estimated yield from the Indian Ocean will be about 11 million tonnes.

## SUMMARY

The paper gives an account of primary production and zooplankton biomass in the Indian Ocean along with a discussion on the present status and future scope for increased exploitation of the fisheries potential.

The part of the Indian Ocean dealt with is between 20° and 120° E longitudes and from the Asian landmass to 45°S latitude, comprising an area of 51 million sq km or roughly two-thirds of the Indian Ocean.

The annual net organic production for this area is estimated to be $3 \cdot 9 \times 10^9$ tonnes, which is about one-fifth of the world oceanic production. The continental

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