Journal of the Marine Biological Association of India

ABBREVIATION: *J. mar. biol. Ass. India*

VOL. 15	June 1973	No. 1

INDIA AND THE INDIAN OCEAN FISHERIES*

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ABSTRACT

This account deals with the present yield and its composition, potential resources-both qualitative and quantitative from the inshore and offshore grounds as well as oceanic areas, in relation to the productivity of the Indian Ocean as evidenced by organic production, plankton biomass and chlorophyll distribution. The paper also includes notes on the different aspects of problem-oriented research and stresses the need for extending our fishing horizon in order to place the Indian fisheries on a firm footing *vis-a-vis* that of countries exploiting the Indian Ocean resources.

INTRODUCTION

INDIA contributes about 40% of the fish landings of the Indian Ocean and ranks seventh among the major fish producing countries of the world. But when viewed against the world production of 61 million tonnes of marine fish in 1970, India's share was only just over a million tonne representing about 2%. At present a quarter of a million persons are actively engaged in actual fishing producing annual landings valued at Rs. 1,200 million. The industry also provides employment to 1.4 million persons. There are about 10,000 mechanized crafts which land 15% of the total production. Over 600 million rupees worth of sea food is exported to different countries. With a coast line of 5,600 km and an operational advantage over wide sectors of the Indian Ocean, India should have a pre-eminent position in marine fish production and this vital sector should play a greater role in the country's economy.

Recent studies made during the International Indian Ocean Expedition reveal that there are several areas in the Indian Ocean which are exceptionally rich in nutrients, chlorophyll, organic production and zooplankton biomass. Consequently these areas could sustain large stocks of fish. This paper deals with the present yield and its composition and the potential resources as estimated from exploratory surveys as well as other biological factors. It also emphasises the possible contribution by India towards a full and rational exploitation of the resources of the Indian Ocean.

*Presented at the 'Symposium on Indian Ocean and Adjacent Seas—Their Origin, Science and Resources' held by the Marine Biological Association of India at Cochin from January 12 to 18, 1971.

The authors thank Shri K. C. George, Central Marine Fisheries Research Institute, for the help rendered in the preparation of the section on inshore and demersal fisheries.

TOPOGRAPHY

The Indian Ocean has an area of about 75 million square kilometres including Antarctica and some of the adjacent seas, as against 106 million sq. km for the Atlantic and 180 million sq. km for the Pacific Ocean. The shallow water areas form about 3. 1 million sq. km in the Indian Ocean. The shelf areas vary in width as well as in surface contour.

The west coasts of India, Ceylon and Pakistan have prominent shelves, whereas on the east coast the shelves are narrow. The east coast of Africa has a narrow shelf except at the southern-most tip. The coastal regions of Mozambique, Tanzania and Kenya are fringed with mangrove and coral reefs. The coasts of Burma, Thailand and Malaysia have a wide shelf with mangrove swamps. The west coast of Australia has a narrow shelf which widens towards the north. The western Indian Ocean Islands have banks which are of both volcanic and coral reef type. The availability of resources have thus to be viewed against the technical feasibility and economic viability of exploitation.

PRESENT YIELD AND ITS COMPOSITION

The fish landings in the Indian Ocean and the pattern of development during the last decade as compared to the Atlantic and Pacific Oceans present a dismal comparison both in the progress and also in the yield ratio in terms of carbon production (Table 1).

TABLE 1. *Fish landings during the past decade and the present yield in terms of carbon production for the different oceans*

Ocean	Fish landings 1958	(million tonnes) 1968	Present yield as % C
Atlantic	13.6	23.1	0.04
Pacific	13.4	31.3	0.03
Indian	1.4	2.2	0.005

The pattern of development in the world fishing shows that at the beginning of this century the total landings were only 4 million tonnes. By 1913 it has doubled to 9.5 million tonnes and again doubled by 1938 to 20.5 million tonnes. The marine landings increased at the rate of 4.5% per year from 1952 to 1958 and picked up speed thereafter, averaging 7.1% per year from 1959 to 1968. After a drop in 1969 it increased by 11.6% (Table 2).

TABLE 2. *World production of fish and rate of increase for the decade*

Year	World production of fish (in million tonnes)	Rate of increase
1960	33.63	7%
1961	36.77	9%
1962	40.05	9%
1963	41.70	4%
1964	46.20	11%
1965	46.50	1%
1966	50.20	8%
1967	53.40	6%
1968	56.60	6%
1969	54.49	-2.8%
1970	61.28	11.6%

Several fishery scientists feel that there is ample scope for further expantion. It has been expressed by some that an increase to 100 million tonnes by the end of this century might be possible without difficulty and in the seventies the probable world catch is expected to touch the 80 million mark. In this important endeavour, Indian Ocean countries and especially India have a challenging task to bridge the gap between present yield and the possible production.

Out of the yield of 2.5 million tonnes from the Indian Ocean, Arabian Sea region provides 9,39,600 tonnes and Bay of Bengal 7,06,900 tonnes. The group of fishes consisting of herrings, sardines, anchovies and related forms contribute about 28% of the total catch from the Indian Ocean. Red fishes, basses and congers come next with 19% of the total yield. The third important group is the crustaceans which account for 12%, the average annual landings being 2,75,000 tonnes of which India's share is 1,50,000 tonnes mostly consisting of shrimps. Tunas, bonitos and skipjacks account for 11% and the group consisting of mackerels, billfishes, etc., account for 8.6% (Anon. 1967).

QUALITATIVE AND QUANTITATIVE POTENTIAL RESOURCES OF THE INSHORE AND OFFSHORE AREAS OF THE INDIAN SUBCONTINENT

It is well known that fluctuations in the pelagic fisheries, mainly the oil sardine and the mackerel, always tell upon the total landings, however much the increased output of demersal fish has contributed to augment or stabilize the marine fish landings of India.

The traditional major fisheries of India such as oil sardine, mackerel and Bombay duck have not undergone any significant changes either in the mode of exploitation or utilisation. But demersal fishing, especially for penaeid prawns, has made rapid strides during the last one and a half decades, in as much as modern fishing methods like trawling have been adopted on a large scale. Utilization of prawns and lobsters has also improved by the adoption of up-to-date processing methods of the catches for export.

Potential pelagic fisheries

The oil sardine and mackeral fisheries, which rank foremost among the pelagic fisheries of India, are known to be fairly well-exploited. A potentially important pelagic fishery which remains very much under-exploited by India is that for the tunas. The main species which abound in our shelf waters are the mackerel tunas *(Euthynnus affinis)*, the skipjack *(Katsuwonus pelamis)* and the frigate mackerel *Auxis* spp. The bonitos(*Sarda* sp.)are also met with in some abundance along the shelf. The annual average landings of these tunas by India is presently a little over 4,000 tonnes. A major portion of this comes from the pole and line fishing for skipjack in the Minicoy and Laccadive Islands. Among the larger and more oceanic forms are the yellowfin *(Thunnus albacares)*, the bluefin *(T. thynnus)*, the bigeye *(T, obesus)* and the albacore *(T. alalunga)*. The Japanese who started post-war tuna longlining in the Indian Ocean now land an annual catch of about 1,75,000 tonnes of tunas and billfishes (Silas, 1969a). Among the four species of tunas most commonly caught by long line gear, the yellowfin is most important.

The common billfishes of the Indian Ocean are the blue marlin *(Tetrapturus audex)*, the striped marlin *(Makaira nigrescens)* and the black marlin *(Makira indica)*. The swordfish *(Xiphias gladius)*. the sailfish *(Istiophorus platypterus)* and the short nosed spearfish *(Tetrapturus anguirostris)* are occasionally caught in long line. Purse seining for *Euthynnus affinis* and *Auxis* spp. has been tried with some success on the shelf waters of the south-west coast in recent years by the Indo-Norwegian Project. During 1968-69, shoals of *Auxis thazard* and *Euthynnus affinis* were observed from October to middle of May with greater concentration of shoals towards latter part of the period (Annual Report of the I.N.P. 1968-69). During the period from 1965 through 1968, drift net operations conducted by R.V. *Varuna* in the Laccadive Sea and on the shelf off the south-west coast caught mainly *Euthynnus affinis, Auxis rochei, A. thazard* and *Katsuwonus-pelamis.* Average catch per fishing operation was 29.33 kg (Silas, 1969 b).

The oceanic squid is another fishery which offers scope for development (Silas, 1969 b). The Japanese are estimated to land 600,000 tonnes from the north Pacific.

Potential demersal fisheries

Trawling in India was introduced since early fifties and this has brought out the potentialities of many inshore fishing grounds off the coasts of India. Side by side, exploratory fishing, mainly trawling, in the deeper waters of the shelf and continental slopes along the south-west coast of India was attempted during recent years. The results of these efforts were highly rewarding from the point of revelation of new resources like the perches, deep water prawns and lobsters (Silas, 1969 b).

The shrimp boats of the south-west coast land ancillary catches up to 80% comprising miscellaneous fishes such as small sciaenids, flat-heads, lizard-fishes, etc. However, certain fisheries like those for the bream *(Nemipterus japonicus)* in the inshore deep grounds of the south-west coast and the east central zone and of the Indian hump head *(Kurtus indicus)* of the north-east coast are worth mentioning as newly located resources with good commercial potentialities. Dominant cat-fish component was noticed from the outer periphery of the inshore grounds in the Cannanore section on the west coast and also off the Andhra coast. Leiognathids were the dominant element in the catches of the inshore grounds along the south east coast.

Productivity of the trawl grounds

Exploratory fishing operations carried out mainly by Government of India vessels, enable a general assessment of the productivity of different trawling grounds along the Indian coast (Rao, 1967; Poliakov, 1962; Tholasilingam *et al.*, 1964 and 1968 C.M.F.R.I. Annual Report). The data obtained so far have been summarised in Table 3.

TABLE 3. *Comparative productivity of Indian trawling grounds*

Region/ grounds	Period of fishing	Method of trawling	Catch per hr. in kg (average/range)
Bombay-Kutch	1957-62	Bull trawling (240 h.p. vessels)	747
	1961-62	Otter trawling(do)	198
Karwar	1963-66	Medium vessels-less than 90 h.p.	150-219
Mangalore	1959-61	do	178-206
	1962-65	do	99-255
Cannanore	1957-58	Bull trawling (240 h.p.)	591
	1960-61	Medium vessels	268
	1965-66	Small shrimp trawlers (25-40 h.p.)	83
Calicut	1957-59	Bull trawling	717-2033
	1960-61	Otter trawling by the bull trawlers	136
Cochin	1957-59	Bull trawling	1015-1184
	1957-61	Medium vessels (less than 90 h.p.)	91-250
	1961-65	do	111-216
Alleppey-Quilon	1957-59	Bull trawling	583-1025
	1959-61	Otter trawling - same vessels	158-187
	1958 60	Medium vessels	105-220
Trivandrum	1957-58	Bull trawling	509
Cape Comorin	1957-58	do	352
Bank	1959-61	Otter trawling . same vessels	69-83
Tuticorin	1963-65	Medium vessels	122-153
Mandapam	1965-66	do	223
Pondicherry	1965-66	do	76
Off Godavary-Mahanadi mouths	1959-60	Otter trawling (240-300 h.p.)	90
Vishakhapatnam	1964-65	Medium boats	78-115
do		15 m Russian trawl	192
Orissa-West Bengal	1961	300 h.p. vessels	2450 kg/day's
coasts	1962-63	do	151 absence

The results of trawling carried out by R. V. *Anton Bruun* at selected places in the Arabian Sea and the Bay of Bengal are relevant in this context. These operations showed that the catch per hour for the Arabian Sea was 123 kg and that of the Bay of Bengal to be 48 kg (Pruter, 1964).

Information now available on certain noteworthy resources recently discovered or rather under-exploited presently are discussed below.

Perch fishery

Perches were caught in trawls mainly on the Wadge Bank and on the north-western trawling grounds. The *Kalava* fishery existing along the rocky out-growths of the south-west coast of India was known for a long time to the local fishermen. They used to go seasonally for handline fishing for these fishes and caught mainly *Epinephelus* spp. Since 1957 several fishing trips were organised by the Indo-Norwegian Project for survey of the *Kalava* grounds of the west coast of India especially south-west part. These operations extended to almost all rocky patches on the continental shelf in 73-110 m depth zone from Trivandrum to Cannanore. Some very productive grounds for line fishing were discovered off Cochin, Chetuwayi and Ponnani. In these grounds the catch composition showed that about 80% by number were *Epinephelus chlorostigma*, 10% *Pristipomoides typus* and 10% of other *Epinephelus* spp. such as *E. areolatus*, *E. diacanthus* and *E. tauvina*. The main species of *Kalava* presently caught in these grounds viz., *E. chlorostigma* ranged from 37.5-61.0 cm in total length and 1-3 kg in weight. The next common species *E. areolatus* measured 48.0-59.0 cm and weighed 0.5 to 2.75 kg. The size range of *Pristipomoides typus* was 46.0-57.5 cm and weight 1-2 kg. It was also observed that on an average a good ground yielded about 50 fish (about 100 kg) per hour of fishing by 3 hand lines using a total of 18-50 hooks.

The grounds now discovered are of great fishery potential but are exploited only meagrely by a few trawlers capable of covering these grounds. Therefore, systematic and more intensive exploitation of these resources is warranted.

Deep water fisheries

The deep water trawling by R. V. *Varuna* during the last few years has indicated the pattern of distribution and availability of various fishes in the hitherto little known grounds on the shelf and continental slopes off the south-west coast of India (Silas, 1969 b; Tholasilingam *et. al.*,1968). *Nemipterus japonicus* was the dominant species in the trawl catches of the 75-100 m depth zone. Other potential fisheries were those of the butter-fish *Psenes indicus* and the lizard-fish *Saurida undosquamis*. Deeper in the 101-179 m depth zone good trawling grounds were noticed north of Cochin for *Nemipterus japonicus, Synodus indicus, Centropristis investigatoris, Emmelichthys* sp., *Priacanthus* sp., *Polymyxia nobilis, Parascolopsis* sp. etc. Of these *Priacanthus* and *Parascolopsis* are good table fishes. Deep-sea prawns of the genus *Metapenaeopsis* occured in small quantities in this depth zone.

Relatively smaller sized species than those of the continental shelf occurred on the upper continental slope (180-450 m). Off Quilon the slope is broad and is now familiar to the exploratory fishing vessels as the Quilon bank. *Chlorophthalmus agassizi, Chascanopsetta lagubris, Epinnula orientalis, Rexea promethoides, Polymyxia nobilis, Pseneopsis cyaenea, Cubiceps natalensis*, etc. were the major species from this zone. Penaeid prawns like *Aristaeus semidentatus, Aristeomorpha woodmasoni, Metapenaeopsis andamanensis* and *Penaeopsis rectacuta* as well as non-penaeids *Heterocarpus gibbosus, H. woodmasoni, Parapandalus spinipes, Plesionika martia* were the important deep-sea prawns caught in the same area. The most significant discovery of the exploratory trawling was the location of commercially exploitable stocks of deep-sea lobster (*Puerulus sewelli*) on the continental slope of the south-west coast of India. These grounds are usually within the 180-275 m zone. Very recently lobster grounds were struck in the Gulf of mannar off Mandapam at depths varying from 133-366 m. The deep-sea lobster grounds were generally sandy with a temperature range of 11° to 17°C. The trawlers of the Indo-Norwegian Project caught about 125 tonnes of the lobster during the period January 1969 to June 70, mainly from the Quilon Bank and adjacent continental slopes. No commercial trawlers have so far been able to operate in the deep water trawling grounds, but however the potentialities of the grounds for lobster, deep-sea prawns and some species of fishes seem very bright.

Some amount of mid water trawling conducted by the Indo-Norwegian Project off the west coast of India revealed the presence of large concentrations of file-fishes (Balistidae) on the shelf from Calicut to Kayamkulam at 50-60 m levels on grounds 60-110 m deep.

Crab fishery

Crabs are possibly one of the under-exploited fishery resources of India. The estimated total landings of marine crabs in India in 1966 were 3315 tonnes. They were landed mainly in the north Kerala and Central Maharashtra regions on the west coast and southern Tamil Nadu Coast. Crabs are caught in trawls at Cochin in good numbers during November-January while on the east coast at Kakinada the season for crabs in the trawl fishery is May to September. The mud banks on the south-west coast of India (May-July) support a good crab fishery. In addition to these marine catches the estuaries and brackishwater lakes are known to yield considerable quantities of crab.

Crab fishery in India could be organised into a better commercial venture and raised from its present status of an ancillary fishery. In this context it is worthwhile to note the fast development of the Alaskan King Crab fishery (*Paralithodes kamchatica*) during the last two decades. Improved techniques of fishing and utilisation are to be practised. Farming of suitable varieties and exploitation of presently untouched inshore and offshore resources are lines on which the fishery could be developed.

Most of the Indian edible crabs from marine and brackishwater environments belong to the family Portunidae. Important among them are:

Scylla serrata - A large edible crab, 150-200 mm across carapace. It is a species likely to be suitable for farming.

Portunus sanguinolentus - Crabs 21-140 mm support fishery.

P. pelagicus - The inshore fishery is generally constituted by 100-150 mm groups.

Charybdis cruciata - This is fished in good numbers from the offshore waters (15-40 m) along the south-west coast. Grows to about 150 mm.

C. annulata - Common along rocky coasts. Attains a size of about 60 mm.

Matuta lunaris - A small crab commonly met with in the inshore waters of the Bombay region.

Varuna littorata - An abundant species of the Sundarbans and Hooghly estuary of Bengal and on the south-east coast in the Gulf of Mannar and Palk Bay. Exceeds 50 mm.

Rao *et al.* (1968) estimated the annual potential resource of marine crabs (up to 40 m and brackishwater areas, at 43,816 tonnes.

Recently swarms of the deep-sea crab *Charybdis* (*Goniohelleaus*) were observed in the Arabian Sea and were caught in trawl (Silas, 1969 b). Another deep-sea crab met with in abundance is *Homola megalops* and these constitute a resource worth further exploitation.

Molluscan fishery

Molluscan resources that can sustain productive fisheries are abundant in Indian waters. The existing level of their exploitation and utilisation as food is low. The pearl oyster and chank fisheries are perhaps the only groups which received attention because of the commercial value of pearls and the chank shells. Mussels and clams are eaten in India mainly by the poorer sections of the society. Except for a few places on the west coast, these bivalves never reach the markets but support sustenance fishery of local importance.

The brown mussel *Mytilus* sp. is confined to patchy beds from south of Quilon to Cape Comorin and up to Tinnevelly district on the east coast. The green mussel *Mytilus viridis* is found in abundance in central and north Kerala. The meat of both varieties is widely eaten by the people of the coastal regions.

The common backwater clams *Meretrix casta* and *Katelysia opima*, the bay clam *Meretrix meretrix* and the black clam *Vellorita cyprinoides* are the principal species supporting clam fisheries on the west coast. *M. casta* is particularly abundant in the south-western coastal backwaters and estuaries. *Meretrix meretrix* occurs in large beds along Bombay region. The black clam is confined to west coast backwaters and estuaries, though dead subfossil deposits occur on the east coast. Extensive subfossil deposits of *Meretrix*, *Arca* and *Vellorita* are found in the Vembanad lake in Kerala and is presently used as raw material for lime and cement manufacture.

The cockle clam *Gafrarium tumidum*, the false clam *Paphia malabarica* and *P. marmorata*, the ark shell *Arca granosa*, the wedge clams *Donax cuneatus* and *D. ecortum* and the finger oysters like *Solen kempi* are the other bivalves fished for food.

Edible species of Indian oysters are *Crassostrea gryphoides*, *C. discoidea*, *C. cucullata* and *C. madrasensis*. The first two are found along the creeks and similar environments from north Kanara to Kutch. *Crassostrea cucullata* is observed all along the rocky coastal areas of the east and west coasts. *C. madrasensis* is found mainly in estuaries and backwaters of the south-west coast and all along the east coast. However, they are used to a much lesser extent than the mussels or clams. The backwater oyster (*C. madrasensis*) is a fast growing species with high tolerance to variation in salinity and could be cultivated for export as well as internal consumption. Simple methods of mussel and clam farming are in vogue in France and some of the Scandinavian countries which could be widely adopted in India. It is known that protein yields from these farms are comparatively very high per unit area.

Several species of pearl oysters of the genus *Pinctada* occur in Indian waters, of which *P. fucata* supports the pearl fisheries of the Gulf of Mannar, the Palk Bay and the Gulf of Kutch. In the Gulf of Mannar these oysters are found on ridges or rock or coral known as *paars* or pearl banks with the most productive areas near Tuticorin, in depths of 20-25 metres about 20 kilometres from the shore. In the Gulf of Kutch pearl oysters are found attached to reeds and they are hand picked at low tides. The window-pane oyster *Placenta placenta* is fished from some areas of the Gulf of Kutch, Bombay harbour and its vicinities and Corangi Bay in Andhra Pradesh. They produce small sized dull seed pearls used for medicinal purposes.

The sacred chank (*Xancus pyrum*) has a well established fishery in the Gulf of Mannar and Palk Bay. Chank beds occur in the Gulf of Kutch and in the sea off Trivandrum on the west coast as well as in the Andaman Sea. The east coast chank beds lie in fine sandy areas (pirals) interspersed with the rocky pearl oyster beds. The shells are used for bangle industry mostly in Bengal. The rare sinistral shell known as 'Valampuri' chank is priced high due to the belief that it wards off evil. The edible portion of the chank consisting of the muscular foot is eaten by fishermen of the south-east coast. It is known to contain good amount of protein, iron and also copper. The possibilities of exporting chank meat are being explored.

Edible gastropods such as *Trochus* spp., *Umbonium vestiarium*, *Turbo brunneus*, *Pterocera lambis*, *Thais* spp. and *Natica* spp. occur in abundance on our coasts but are little used for food. The fishery for *Trochus* and *Turbo* in the Andaman and Nicobar Islands is due to the commercial demand for 'mother of pearl'.

Cuttle fish, squids and octopi are caught incidentally in fishing nets. When caught in large quantities they are sun-dried for export. There is a seasonal fishery for squids (February to June) on the southern coast of Palk Bay and Gulf of Mannar, the chief commercial species being *Sepioteuthis arctipinnis*. Recent exploratory drift net fishing by R. V. *Varuna* revealed the presence of the oceanic squid *Symplectoteuthis oualaniensis* in abundance between 8°N - 14°N lat. along the continental slope and beyond (Silas, 1969 b). Squids are a much relished item of food and an underfished resource.

STANDING CROP, PRIMARY PRODUCTION AND POTENTIAL YIELD

As the concentration of phytoplankton pigments gives a direct estimate of the magnitude of the standing crop, the pattern of distribution of the pigment especially chlorophyll *a* in the ocean gives a broad outline of the scope of fisheries potential.

The average amount of chlorophyll *a* for the entire Indian Ocean is found to be 14.81 mg/m^2 (integrated values up to 200 metres). On the west coast of India alone it is 25.41 mg/m^2 and on the east coast it is 8.24 mg/m^2 (Nair and Joseph, 1971).

In the western Indian Ocean during south-west monsoon extremely high values are found mainly in the area off Cape Guardafui and Socotra in the upwelling regions associated with Somali current. High values of primary production (Prasad, *et al.* 1970) and zooplankton biomass (Prasad, 1968 a and b, 1969) are also observed in this area. Such high values are not found during the north-east monsoon period apparently failing to provide any such nutritional enrichment in the open sea. But in the Red Sea a considerable increase in the integrated pigment values, even higher than those obtained during south-west monsoon period, is observed. These estimates may reflect seasonal blooms.

The distribution pattern of chlorophyll *a* shows that the level of pigment concentration per unit area is almost the same to that of Atlantic and Pacific Oceans even though the concentration per unit volume is slightly lower in the Indian Ocean (Humphrey, 1966).

Laird *et al.*, 1964 state that the area off the Somali coast, Longitude 57° East between Latitude 10° North and the equator could support excellent fisheries during the south-west monsoon period. This conclusion is based on chlorophyll studies in the western India Ocean.

The data now available from various sources on standing crop, primary, organic production, chlorophyll values and exploratory fishing reports enable us to make a broad appraisal of the potential resources. The net production of the marine environment has been computed at 2.2 - 2.8 x 10^{10} tonnes of carbon per year (Vallentyne, 1965). In terms of the efficiency of yield the present world landings are only 0.02 or 0.03%. For the Atlantic Ocean this ratio is 0.04% and for the Pacific Ocean it is 0.03%. Taking only the Indian Ocean the ratio is found to plummet down to 0.005% (Table 1). Not that the organic production of the Indian Ocean is less but the processes of fishing have to catch up. In intensely exploited waters this ratio can even rise up to 0.4% which seems to be the optimum.

There is a great amount of spatial variation in the magnitude of organic production in the Indian Ocean. The shelf areas which sustain the bulk of the landings at present are on the whole having a high rate of production. Because of the constant replenishment of nutrients in the surface layers the shallow water areas of the tropics are generally productive. An average rate of 0.5 to 1.0 gC/m^2/day is observed in most of the shallow areas. Studies conducted for prolonged periods in near-shore areas around the south-east and south-west coasts of India have shown that rate of production exceeding 2.0gC/m^2/day are also found especially at the time of upwelling.

In the oceanic regions at middle latitudes in the western part of the ocean, outside the continental shelf, the production rates observed by *Galathea* were between 0.1 to 0.2 gC/m^2/day which is the value normally found in tropical and subtropical oceanic regions in the absence of any pronounced admixture of nutrient-rich water from below (Steemann Nielsen and Jensen 1957). Over the shelf the average rate was 0.51 gC/m^2/day. In the South Equatorial Current a relatively high production rate of 0.22-0.23 gC/m^2/day was found. For the western Indian Ocean Ryther *et al.* (1966) observed two large areas of low production—one to the north extending from 80° to nearly 60° E longitude and from the Indian subcontinet to about 5° S latitude and another from 10° to 40° S latitude and from 80°E longitude nearly to the African coast south of Madagascar. These authors also observed moderately productive water (0.26-0.50 gC/m^2/day) between 5° and 10° S latitude. Pockets of high producton with rates exceeding 1.0 gC/m^2/day were noted along the south-east coast of Africa.

In the Arabian Sea the leval of organic production increases to the north and west, reaching exceptionally high values off the coasts of Saudi Arabia and West Pakistan. The Arabian Sea when considered as a whole is a region of great contrast. Measurements in the north-western Arabian Sea showed values in excess of 1.0 gC/m^2/day with a maximum of 6.4 gC/m^2/day (Ryther *et al. loc. cit.*). Based on *Anton bruun* survey these authors calculated the annual production for 23 x 10^6 sq km, i.e., one-third of the conventionally described Indian Ocean, as 3 x 10^9 tonnes of carbon which gives an average value of 0.35 gC/m^2/day.

In the eastern Arabian Sea towards the coast of India the average rate within 50 m depth comes to 1.19 gC/m^2/day and for the rest of the shelf a rate of 0.43 gC/m^2 day is found which is moderately high. Allowing 40% of the production for respiration, the net production for the shelf area on the west coast of India has been computed as 46 x 10^6 tonnes per year (Nair *et al.*, 1968). Outside the shelf the level of organic production falls to less than 0.2 gC/m^2/day.

But as this rate persists through out the year an annual net production of 50 gC/m²/day can be expected with higher rates in the regions of deep-water ascent and around the oceanic islands.

For the Bay of Bengal the available data show that the average production rate is 0.19 gC/m²/ day in the deeper part while in the shelf region it is 0.63 gC/m² / day. The net production for the shelf region on the east coast of India has been computed at 15×10^6 tonnes of carbon per year or about one-third of that on the west coast.

Based on these estimates Prasad *et al.* (1970) calculated that the annual *net* production for 51 million square kilometres of the Indian Ocean as 3.9×10^9 tonnes of carbon. Of this 2.3×10^9 tonnes of carbon is for the western region comprising 29 million square kilometres and 1.6×10^9 tonnes for the eastern region with 22 million square kilometres, the dividing line being taken as 80° E longitude. The continental shelf areas which form only 6% of the total area account for 560×10^6 tonnes or 14% of the total net production. Of this, Indian coastal regions as indicated above contribute 61 million tonnes which is roughly 1 tonne per hectare or 150 gC/m² year.

As mentioned before, in heavily exploited areas of the North Sea and the English Channel, where optimum catch is obtained it has been observed that carbon content of optimum fish catch divided by net production which is 60% of gross production gives a ratio of 0.004. Hence the potential yield is 0.024 C where C is the gross carbon production. Thus for a production of 1.2 gC/m2/day the annual potential yield of fish is about 105 kg per hectare. Based on organic production data the probable potential increase has been worked out for the various regions (Table 4).

TABLE 4. *Present yield as %C and the probable potential increase for the various regions*

Area	Yield rate as %C	Probable potential increase
Atlantic	0.04	—
Pacific	0.03	—
World Oceans (mean)	0.02	x 2
Indian Ocean	0.005	x 6
Continental shelf of Indian Ocean	0.03	x 10
Gulf of Mannar	0.07	x 5
West coast of India	0 22	x 2
East coast of India	0.14	x 3

The potential yield of fish for the entire continental shelf area of India as derived from productivity studies, has been found to be 2,288,000 tonnes of which the share of the west coast is 1,417,000 tonnes (Jones and Banerji 1968). This estimate includes both pelagic and demersal fish. The percentage of demersal fish in the total catch varied from 28 in 1966 to 33.5 in 1969 (Table 5). Assuming the ratio of demersal fish to be 30% on an average, the potential

TABLE 5. *Catch from exploited stock. Estimated regionwise distribution of pelagic and demersal fish catch based on the data collected by the Central Marine Fisheries Research Institute for 1969*

State	Pelagic	Demersal	Total
Gujarat	68,551	18,034	86,585
Maharashtra	49,379	74,537	1,23,916
Goa	16,135	2,753	18,888
Mysore	66,998	20,824	87,922
Kerala	2,81,816	63,485	3,45,301
Madras W. coast	15,181	6,295	21,476
Madras E. coast	60,225	72,699	1,32,924
Pondicherry	4,575	3,576	8,151
Andhra	42,457	34,972	77,429
W. Bengal & Orissa	14,375	16,283	30,658
Laccadives	757	363	1,120
Andamans	223	118	341
Total	6,20,672	3,13,939	9,34,611

demersal catch for the entire Indian shelf area will be 7,00,000 tonnes and the potential pelagic yield about 1,600,000 tonnes. If intensive exploitation is possible for the entire shelf area of the Indian Ocean which comprises 307 million hectares, it would be possible to obtain an yield of 11 million tonnes from these areas. Hence theoretically a five fold increase from the present level of exploitation should be possible even from the stocks available within the continental shelf with India's share at 2.3 million tonnes or almost the present production from the entire Indian Ocean.

When these theoretical estimations are examined in the light of exploratory fishing data, available through many reports which have appeared in recent years, we obtain more or less the same picture(Anon, 1958 a, b; 1962; Bell & Ochi 1965; Kerr 1966; Kristjonsson 1956and 1958; Losse 1963; Masuda *et al.*, 1964; Postel 1965; Reed 1964; Rhodes 1966; Shomura, *at al.* 1967; Tiews 1966; Wheeler and Ommanney 1953; Rao 1969; Silas 1969 b).

As assessed from these exploratory surveys, the potential catch from the East African coastal fishery is 1,25,000 tonnes of fish. Demersal fishery of the offshore banks is considered to be very high amounting to 2-3 million tonnes. The potential yield from the Arabian Sea region has been estimated at 8,50,000. tonnes of demersal fish and 1,790,000 tonnes of pelagic fish with a sizable proportion of crustaceans amounting to 2,00,000 tonnes. Including the Red Sea and Persian Gulf resources the annul potential yield for the western Indian Ocean has been estimated at 6 million tonnes (Prasad *et al.*, 1970). For the Eastern Indian Ocean the potential yield is 1,281,000 tonnes of demersal and 1,540,000 of pelagic fish. Including Indonesian waters and Australian shore the potential yield has been estimated at 3.22 million tonnes. With the oceanic tuna resources the potential yield as deduced from the exploratory surveys is 10-11 million tonnes of fish. The share of India towards the Indian Ocean production of fish is thus 2.4 million tonnes (1.6 million tonnes from the west coast and 0.8 million tonnes from the east coast) which means nearly a three-fold increase from the present level of exploitation. The rather close similarity in the values of potential resources as derived from productivity values and exploratory fishing data is striking and lends validity to each other.

Table 6 gives a consolidated account of the potential resources of the various regions.

TABLE 6. *Annual potential yield from the Indian Ocean (in 1000 tonnes)*

Zone	Demersal (incl. crustaceans)	Pelagic	Total
East African coast	120	5	125
E. African offshore Bank	3000	—	3000
Somalia	—	—	8
S. Arabia, Muscat, Oman	100	650	750
West Pakistan	160	90	250
India (west coast)	580	1020	1600
Maldives, Laccadives, Chagos etc.	7	23	30
Red Sea	125	25	150
Persian Gulf	55	40	95
India (east coast)	143	672	815
East Pakistan	98	250	348
Burma	326	400	726
Thailand (west coast)	58	20	78
Malaysia (west coast)	600	100	700
Ceylon	52	90	142
Andaman and Nicobar	4	8	12
Indonesia	90	260	350
Australia	30	20	50
Oceanic (tuna)	—	—	450
Total	—	—	9,679 or 10 million

NEED FOR EXTENDING THE FISHING HORIZON

In general, the total marine fish production of India has been showing an increase but considerable fluctuations are noticed in the annual landings in certain years. Three fisheries viz., oil sardine, Bombay duck and mackerel constitute nearly forty-two per cent of the total catch and the landings of each of these show wide variations. The highest landings of marine fish take place during October-December which coincides with the peak fisheries for the three mentioned above. Thus, the success or failure of these three fisheries will be the main determining factor of the total marine fish production of India.

The overall picture that emerges from the vast amount of environmental data collected in recent years is one for optimism and points to the scope for stepping up the production of certain varieties and intensifying efforts in certain areas. At the same time a groupwise study of the trends of fisheries indicates that some of the coastal and near-shore fisheries along the coast of India are quite intensively fished. Based on data extending from 1951 to 1965, Nair (1970) observed that while oil sardine, elasmobranchs and silver-bellies show an increasing trend other groups such as mackerel, Bombay duck, crustaceans, sciaenids, anchovies and whitebaits, ribbon-fishes cat-fishes, carangids, other clupeids and pomfrets show a decreasing trend. An examination of the data collected by the Central Marine Fisheries Research Institute subsequent to 1965 does not, however, substantiate the observations of Nair (1970) in respect of all the groups mentioned by him (Table 7).

TABLE 7. *Total landings of selected groups of fish for 1965-1969 (in tonnes)*

Groups	1965	1966	1967	1968	1969
Crustaceans	79,765	97,838	94,630	1,05,737	1,13,292
Bombay duck	73 894	77,363	74,882	82,501	76,260
Mackerel	43,095	31,959	29,194	21,703	91,837
Other clupeids	18,770	23,262	22,332	26,297	26,275
Pomfrets	17,892	17,845	27,460	28,235	24,091
Sciaenids	23,673	26 032	25,458	28,305	34,925
Anchovies and whitebaits	29,188	35,516	38,459	28,499	40,445
Ribbon-fishes	41,921	45,124	29,463	28,667	31,711
Cat-fishes	18,915	22,572	24,299	24,749	26,831
Carangids	17,699	19,812	24,495	18,625	21,422

It will be seen from this Table that mackerel which showed a downward trend up to 1968 increased significantly in 1969. In the case of ribbon fishes and anchovies and whitebaits, the trend seems to be more erratic than a consistent decreasing trend. All the other groups, reported by Nair (1970) to be showing a decreasing trend, are actually showing an increase subsequent to 1965. In this connection particular mention may be made of prawns. The landing figures show that the penaeid prawns, which constitute the export variety, the catch has increased from 38,085 tonnes in 1965 to 73,659 tonnes in 1969. Mohamed (1969) while discussing the trends in crustacean fisheries remarked "A detailed analysis of the commercial landings of each of the constituting categories of crustaceans showed diverse trends of production. Within normal fluctuations, the landings of penaeid prawns are seen to increase year after year and its total production of a little over 37 thousand tonnes recorded in 1950 has reached about 70 thousand tonnes in 1968."

The examination of catch trends of the various groups of marine fish in conjunction with the effort put in would certainly indicate that some of our near-shore fisheries are under heavy pressure and a time has come when close watch over the trends is called for. Banerji (1969) pointed out that judging by the criteria for establishing instances of overfishing, only in a few cases there are indications of overfishing. According to him the polynemid and sciaenid fisheries off Gujarat are two clear cases. It is likely that due to intensive fishing for these demersal fishes in that area localized overfishing might have resulted. In the case of Bombay duck, Banerji (1969) remarked that since there was no decrease in the average size of the fish the tendency of declining catch in recent years might be due to changes in availability. Further, the catch figures for Bombay duck given in Table 7 would indicate that the catch trend is increasing from 1965 onwards.

Considering all factors there is no gainsaying the fact that after the introduction of mechanised fishing, the fishing intensity has substantially increased particularly on the demersal resources of the near-shore waters. This continued increase would probably result in overfishing if we are not sufficiently vigilant. Therefore, to avoid a crisis, it is necessary to have a constant watch of not only our inshore resources but offshore resources also as we have reasons to believe that, at least in a few cases, the exploitation of one would affect the other.

We have to go a long way in exploring the resources of our offshore waters. Nevertheless, the investigations and surveys carried out both along the west and east coasts of India have demonstrated the existence of new and hitherto unexploited and certain under-exploited grounds. Similarly in the case of pelagic fisheries, there is ample evidence to show that appreciable increase in our catch is possible. In this context, it may be stated that according to the statistics of Japanese Tuna Fisheries (1969) the lowest catch of tuna from the Indian Ocean is being made by India. The data presented in this report clearly indicate what our country could achieve in increasing our fish production provided the industry is developed in a proper broad-based manner.

A CASE FOR CO-OPERATIVE AND PROBLEM ORIENTED RESEARCH

The days are over when the seas and oceans are looked upon only as channels of trade routes, for colonization of distant lands, search for legendary treasures and riches or for the mere thrill of exploring the unexplored regions. The spirit of enquiry has enabled mankind to penetrate beyond the mysteries of the oceans which revealed to him the vast potential resources in the form of energy, minerals and food.

This opened up new research and technical problems. While the oceans hold many secrets and and we still have not fully understood about the resources that could be exploited, there are concerted efforts made to study in detail these resources and how to exploit them to our best advantage. We are also equally conscious that in exploiting these resources it is our responsibility to make sure that it is done rationally because "it is a despicably inhuman thing for the current generation wilfully to make the way of life harder for the next generation, whether through neglect of due provision for their subsistence and proper training or through wasting their heritage of resorces and opportunity by improvident greed and indolence."

The living resources of the sea, though self-generating, are by no means inexhaustible. This concept logically would lead to the inevitability of a scientific approach in the exploitation of these resources. To many, fisheries research is synonymous to research on fish but one has to differentiate between these two. In this context the remarks of Kesteven (1969) are relevant. "I think that nothing need be made of the fact that I deal with research on marine fishes as an enterprise separate from the rest of oceanography. I readily concede that oceanography embraces studies of fishes, since fishes are, of course, part of the biota of the seas and by convention the term oceanography denotes any and all studies of the seas, including studies of their biota. It is also true, however, that fisheries research has a special character in methodological sense (as agricultural research differs from botany) and that studies of fishes (as part of fisheries research) are often separate from general oceanography in several senses other than those that are a consequence of its economic orientation." Herein lies the need for the formulation of problem-oriented research so that the various technical problems raised by the need to exploit the resources of the ocean could be solved.

India with its extensive coastline and urgent need to find adequate quantity of cheap animal protein can ill afford to indulge in the luxury of too much fundamental research. It may be argued that unless fundamental knowledge is available, it cannot be applied. Certain amount of fundamental research is no doubt inescapable and in selecting and alloting priorities for such research problems extreme care is necessary in limiting them to those which are essential for providing data required for immediate application. Such caution and circumspection are particularly imperative in marine fisheries research which is expensive and extremely complex. The spectacular advancement in science in recent years has resulted in the establishment of numerous new disciplines and sub-disciplines. In many areas of research an inter-disciplinary approach has become essential, as rigid compartmentalization would impede the progress of scientific research. While this is a general axiom, this is particularly true of fisheries research which is multidisciplinary. Therefore, in order to get the desired results within a reasonable period of time a co-ordinated and combined effort of the various displines involved is essential. Similarly, the vastness of the ocean which presents problems of adequately sampling it and the complexity of the environment all point to the need for concerted effort of not only the different agencies within a country but of all countries if we are to achieve any progress in the rational exploitation of the resources of the sea. This calls for a massive and bold programme.

For several years different organizations within our country have been engaged in research in the field of marine biology, oceanography and fisheries. A vast amount of valuable data have been collected and several scientific papers have been published based on these. But it has to be regretfully admitted that while these investigations have certainly added to our knowledge of marine biology or oceanography or of fish, these have not enabled us to provide satisfactory answers to many of the basic problems in fisheries. In the field of fisheries research, it has to be admitted, that the results achieved have not been commensurate with the efforts put in to study the problems. Co-operation and co-ordination between interested agencies in the field have been lacking and the projects undertaken particularly by the fisheries institutes have not been always problem oriented. These have mainly contributed to the slow progress in achieving the desired results.

Recently the Indian Council of Agricultural Research has undertaken a new programme through planning and execution of agricultural research including animal husbandry and fisheries on a national basis. The genesis of the philosophy of these All India Co-ordinated Projects is through the lessons learnt from operating the so-called "*ad hoc* research schemes" financed by the Council until recently. The council recognised the fact that such *ad hoc* schemes in an isolated and un-coordinated manner were for various reasons not a very effective approach to the solution of research problems in the country as a whole. Consequently, the Council has now decided to sponsor several major All India Co-ordinated Projects and in the field of fisheries seven such projects have been formulated.

There is an increasing awareness now all around on the need for a scientific approach to the development of our fishery resources but in the actual implementation of the various research projects there are many bottlenecks. Procurement of adequate funds, for example, continues to be a major hurdle. A more autonomic structure in scientific research administration would go a long way in removing this hurdle and allow more flexibility in the functioning of the concerned agencies. Efforts have been made to re-orientate the objectives of the fisheries research institutes and also to create a healthy climate for the scientists to enable them to turn out better and more useful work. The Indian Council of Agricultural Research has taken active steps to bring about inter-organizational co-operation in reseach. With the ideal of co-operative research and problem oriented programmes we can be certain that the fisheries research institutes will become more functional and of immediate and direct assistance in the development of our rich fishery resources.

The Indian entrepreneurs have been rather shy to venture forth beyond the traditional fishing areas near the coast in search of pastures fresh. This reluctance is partly due to the lack of reliable information on the potentialities of these un or under-explored regions and consequent fear of a 'no return' for the heavy investment. For this lacuna in our knowledge both the resarch/developmental agencies of the Government and the industry are equally responsible. While it is expected of the research/developmental agencies to carry out investigations and exploratory surveys on these aspects, as beneficiaries it is obligatory on the part of the industry to have close involvement in these programmes by free exchange of data and financing specific areas of research of short term duration which will make an immediate impact on their own future developments.

In this context it may be mentioned that the formation of the Indian Ocean Commission is timely and highly commendable. In has a very major role to play in bringing together the countries bordering the Indian Ocean for a common purpose. Let us, therefore, forge ahead in a spirit of co-operation and use the tools of modern science for creating an era of plentiful, wholesome fish on a sustained basis.

CONCLUSION

The potential resources of the Indian Ocean, as calculated from plankton, chlorophyll and primary organic production, are estimated to be between 39 to 40 million tonnes and at the present level of world exploitation the estimated yield from the Indian Ocean could be about 10 million tonnes. This increase is possible mostly from the pelagic resources and those from the under-exploited and un-exploited areas in the offshore demersal stock, as appreciable increase from the inshore area may not be possible. Introduction of modern techniques of fish finding, better and more efficient fishing crafts and gear, development of techniques for economic harvesting of the rather thin stocks of several known varieties, and better utilization of the latent resources would enable us to increase substantially our fish production.

In the immediate future, developments in the fishing methods are likely to be mostly in terms of medium or small sized fishing units and the fact that some resources in the inshore areas are showing signs of being subjected to heavy fishing intensity, a time has come when we have to be vigilant. It is also necessary to have a close look at the resources of the inshore and the offshore areas, as these are invariably closely related, and formulate a rational, well-coordinated long term plan of action which would produce the maximum sustainable yield.

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