SOME ASPECTS OF PRODUCTIVITY IN RELATION TO FISHERIES OF INDIAN NERITIC WATERS

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Introduction

It is generally accepted that tropical seas are less productive than the temperate waters to the north and south of the Equator. Large concentrations of nutrients are characteristic of Polar waters and areas influenced by these waters are rich in animal and plant life. In temperate waters the nutrients accumulated during the winter months support the burst of phytoplanktonic growth which reaches its peak with increasing sunlight; the tropical waters which do not accumulate nutrients in the same manner are held not to show major peaks but an even trend of production of life throughout the year. Recent studies have, however, indicated that this concept can only be accepted with many reservations because there are known areas of high productivity in the tropical zone, where special physical factors may operate which bring the nutrient laden bottom waters to the surface. Some of these exceptionally fertile areas have been known to biologists for a long time, and fully confirmed in recent years by the phenomenal progress in Tropical Tuna Fisheries. Further, it has been indicated by many workers (Clarke, Riley and others) that the estimates made on the basis of standing crop alone cannot be taken to establish any fundamental difference in the rate of organic turnover when it is remembered that organic production takes place throughout the year in the substantially larger euphotic zone of the warmer seas.

Problems of Productivity

In comparing the organic productivity of waters of different regions, a knowledge of the distribution and seasonal cycle of nutrient salts is quite essential. There is sufficient volume of data in this respect for the waters of the temperate and colder regions. In the tropical waters, on the other hand, not much systematic work has been done and hence not much comparable data are available.

A knowledge of the distribution of nutrient salts in any area is by itself insufficient for a proper assessment of organic production.

The concentration of nutrient salts in a water mass at any time is only a momentary balance between their consumption by the phytoplankton and their regeneration by the animals. "In comparing two different water masses, a smaller average standing crop and a lower concentration of nutrient salts does not necessarily mean a smaller production of organic matter, if other conditions such as light and temperature allow more rapid growth of the plants . . ." (Harvey, 1945). The amount of nutrients in the productive zone is no doubt a measure of potential production; but the actual fertility is determined more by the rate of replenishment of nutrients at this zone than by the actual concentration observed at a particular time (Ketchum, 1947). The replenishment is provided by decomposition and water circulation. When there is active regeneration *in situ* in the surface layers, the nutrients are readily available for organic production. If the regeneration takes place in the deeper waters, as is more often the case, the regenerated nutrients have to await transport to the surface layers before being made available for consumption by plants.

It may therefore be seen that the assessment of organic production in an environment does not lend itself to direct attack; several of the factors enumerated above have to be considered before arriving at any estimate of production. A knowledge of the distribution of nutrients is, however, considered to be the basis on which various theories of productivity have been founded.

Its Application in the Indo-Pacific

The subject is of interest and importance because of the search for more food from the seas in areas situated within the tropical belt where the population pressure is high, rendering the development of additional sources of food from the sea a world necessity. Many countries within the tropical zone and especially those bordering the Indian and Pacific Oceans are taking active interest in the development of their fisheries. A discussion on this subject is therefore most appropriate because apart from the value of such a discussion in assessing the present views on the problem, it would help focus attention on aspects of research requiring close attention in these countries. Any lead which these discussions could give to develop and orient the research programmes would be of practical benefit in the mobilization of scientific effort in an area which is admittedly backward in both equipment and personnel.

There is ample evidence to show that even within the tropical zone as elsewhere, there are areas which are both highly productive and comparatively barren. In many instances the reasons for such marked

differences within closely adjoining areas and in the same latitude are not fully understood. An intergrated oceanographical and fisheries programme might perhaps give us some explanation. In areas where fish landings could be studied and different regions compared some idea of comparative productive value of adjoining waters could be gathered. What is equally necessary is the research on productivity which could precede exploitation to map areas which may have potentially valuable fisheries at present unutilized.

Sea Fisheries of India

It is clear from a study of the sea fisheries of India that very marked differences exist in the amount of fish production on the two coast lines of India lying in about the same latitude. Table I shows the production of sea fish from the various sectors of the Indian coast line as estimated by statistical samplings of fish landings by indigenous crafts. With the exception of a small number of powered vessels operating from Bombay and which at present do not substantially affect the total yield of sea fish, the fish landed in India come entirely from the landings of indigenous craft and gear working only within the narrow strip of the coast line mostly within five miles and in any case not exceeding ten miles from the shore. The fish are therefore entirely from neritic waters, although not all areas lying within the continental shelf are fished.

TABLE I

Production of Sea Fish in India

Zones	Extent of Coastline in Miles	Average Annual Catch for 1950-52 (In Tons—2,224 lbs.)	Annual Catch per Mile
East Coast:			
1. West Bengal & Orissa	369	8,825	23.92
2. Andhra coast (south of Gopalpur to north of Visakhapatnam)	159	31,561	198.50
3. Andhra coast (Visakhapatnam to Masulipatnam)	194	30,878	159.16
4. Andhra coast (south of Masulipatnam to north of Pulicat Lake)	249	954	3.83
5. Coromandel coast (Pulicat Lake to Cuddalore)	139	17,518	126.03
6. Coromandel coast (south of Cuddalore to Devipatnam)	222	8,299	37.38
7. Palk Bay & Gulf of Manaar	240	8,144	33.93
West Coast:			
8. Travancore, Cochin and South Malabar (Cape Comorin to Ponnani R.)	263	117,010	444.91

9. Malabar & South Kanara (north of Ponnani R. to Mangalore)	171	118,136	690.85
10. Kanara, Karwar & Konkan coast (north of Mangalore to south of Ratnagiri).	307	64,144	208.94
11. Bombay & Gujarat coast (Ratnagiri to Broach)	386	113,666	294.47
12. Kathiawar coast (Broach to Pakistan Border)	500	16,582	30.48
All-India Total	3199	535,716	165.19

The figures bring out clearly that of the total sea fish production of the country, between 65 and 75 per cent comes from the west coast of India and only the remainder is caught on the east coast. The west coast fishermen are no doubt better organized and able to take advantage of the harvest, but the difference in production is not entirely due to this because there is a corresponding reduction in the per capita landings between the east and west coasts. Even the best fished areas of the east coast do not compare favourably with any strip of the west coast of India. If a closer analysis is made of the different zones of the west coast, it becomes clear that the higher landings are to the south, the highest landings being on the Malabar Coast with the Travancore-Cochin coast coming next.

What are the features that go to make the west coast of India so highly productive as compared with the east coast in the same latitude? Hydrologically, the Bay of Bengal and the Arabian Sea seem to present substantially different features although the differences in temperature and salinity are not appreciable. A fairly clear picture of the hydrology of the two seas is available from the work of Sewell on the 'Investigator' and the results of the John Murray Expedition on the Arabian Sea.

Hydrological Background

Although information on the water masses forming the Indian Ocean is by no means complete, the general ideas have been summarized by Schott (1935) and Sverdrup *et al.* (1943). The waters include three distinct components, viz. the Indian Equatorial water, the Indian Central Water and, running between the depths of the above two, the Deep waters of the Indian Ocean which is continuous with the Antarctic bottom waters. The latter drift into the Indian Ocean in a few distinct regions, a tongue of it proceeding in the direction east of Madagascar and grazing the Seychelles/Mauritius bank, the second moving in the direction of the Carlesberg submarine ridge and a third forming

an arc converging on the southern part of India and Ceylon in a south-easterly direction, but later going round Ceylon, one branch going westward in the direction of the Laccadive-Maldive Archipelagoes and the other entering the Bay of Bengal. High salinity waters from the Red Sea enter the western part of the Arabian Sea and generally the salinity of the Arabian Sea is higher than that of the Bay of Bengal, the latter also being substantially influenced by the large volumes of fresh water brought down by the numerous rivers. It may be generally said that the waters of the Arabian Sea, being part of the Indian Ocean, are of an oceanic character while that of the Bay of Bengal are predominantly of the estuarine type. The temperatures in both the seas generally range from 25° to 30°C, with values between 21° and 25°C during the monsoon months in some areas near the coast. Annual amplitude is normally within 2°–5°C. in the Bay of Bengal and 3°–5°C. in the Arabian Sea. Areas of higher amplitude are seen at the head of the Bay of Bengal (5°–10°C.) and the Gulf of Oman.

It has been indicated from the results of the John Murray Expedition that the influence of the bottom Antarctic waters which come to the surface when these waters strike the submarine ridges in the Mascarene bank and the Carlesberg-Murray ridges is most marked in increasing the productivity of the surface waters. The areas which are particularly rich are to the east of Seychelles-Mauritius Bank. The general oceanic concept that deep moving waters come to the surface when confronted with submarine ridges is generally employed in the explanation of the richer areas in the Arabian Sea.

The Arabian Sea and the Bay of Bengal are subject to the monsoons. The strong southwest monsoon winds on the east coast of Africa driving waters away from the shore results in the upwelling of waters which forms a northerly current, the Somali current which flows along the east coast of Africa, later towards northeast in the direction of Arabia, finally moving south along the coast line of India. Sewell has pointed out that the cause of the rich fisheries in the west coast of India is to be sought in this current which brings in its train the cold waters rich in nutrients. It seems probable that the rich coastal fisheries off the Arabian, Mekran and Pakistan coasts are formed as a result of this current, but it is for further investigation as to how far the current grazes further south and influences the fisheries.

Special Features of the West Coast of India

The bulk of the west coast fisheries in the highly productive zones of Travancore-Cochin and Malabar is constituted of plankton feeding fishes, the Sardines and Mackerel, which account for about 30% and

25% respectively of the total catches. The former group includes several clupeoids of the Genus *Sardinella* and related forms, but the most valuable is the oil sardine of Malabar, *Sardinella longiceps*. The mackerel is composed only of one species, viz. *Rastrelliger kanagurta*. Both the fisheries extend from almost the southernmost part of the peninsula to some distance south of the Bombay coast. There is a distinct and unmistakable gap in the distribution of the major fisheries to the north of Ratnagiri. North of this place shoals of mackerel are not known, but the species is certainly widely distributed having been found in the Persian Gulf and in the Bay of Bengal and stray specimens have also been taken in the trawls operated off Kathiawar. Smaller shoals of mackerel have been encountered near the coast in the Bay of Bengal at several places. Although both the species are widely distributed in the Indo-Pacific, the special reason why large shoals occur only in the Travancore-Cochin, Malabar and the Konkan coasts is a problem which requires examination. If, as is assumed, the nutrient laden current supporting the rich plankton extends from the northerly direction, the fish should occur in shoals at much higher latitudes and further the shoals appear first in large numbers towards the equator and then only spread to the north. Purely on distributional grounds it would be reasonable to expect the shoals getting their sustenance from the southeast part of the Arabian Sea, and at least as far as the mackerel and sardine fisheries are concerned, it is probable that either the coastal turbulence following the southwest monsoon or local upwelling between or near the Laccadive-Maldive Archipelagoes are probably significant.

Mud Banks of the Malabar Coast

The Malabar coast has also certain characteristic physical features which would appear to play an important role in the retention and release of nutrients to the coastal water. Soon after the monsoons, fine particles of silt become distributed in the coastal waters and with the decline in strength of the winds and currents, this silt settles in the form of fine mud forming a bank extending from about the region of Alleppey to the areas north of Calicut. The mud bank is fluid and movable and exists often at sub-surface levels in the form of fine silt in the process of settling and geologists believe that its occurrence and movements are somewhat connected with the heavy monsoon rainfall of the Malabar coast, the weight of the large amount of water that is brought down into the coastal tracts pressing out the soft mud from its subterranean formation. Whatever be the explanations for the formation of the mud bank, the fact remains, as has been conclusively demonstrated by my colleague Seshappa (1953), that large quantities

of nutrients, especially phosphates, are found in the interstitial waters of these mud particles. Apart from dissolved phosphates there is also a large quantity of adsorbed phosphates which is released into the waters when the mud bank is agitated. The highest phosphate values are during the monsoon months June–July with subsequent smaller increases in the North-East monsoon of the September–November period. The exact relationship of the mud bank formation with the Fisheries yet remains to be elucidated, but it is an aspect of marine studies which seems to require development in tropical areas subjected to strong currents and winds. Its relationship to plankton production is also important because the banks render the waters turbid substantially reducing the depth of the euphotic zone.

Swarming of Planktonic Species

Enrichment of surface waters by upwelling or other physical agencies is also illustrated by the widespread prevalence of planktonic outbursts of small flagellates, the dinoflagellate, *Noctiluca,* and the blue green alga *Trichodesmium*. On the Malabar coast the swarming of *Noctiluca* is known to cause abrupt setbacks in Fisheries (Bhimachar and George, 1950) and such instances are not unknown on the east coast of India (Madras, Aiyer, 1936). Swarming of flagellates on the Malabar coast has been known to cause mortality of fishes. These flagellates have been termed differently by various authors, but it has recently been shown by Subrahmanyan (1953, unpublished) that it is a member of the Chloromonadinae, belonging to a genus new to science. In the Palk Bay area a sudden increase in numbers of *Noctiluca* is known to reduce the output of the sardine fisheries (Prasad, 1953) and unpublished observations of Prasad and Jayaraman (1953) indicate that swarming of *Noctiluca* also introduces noteworthy chemical features like increase in the amount of silicates, and it may be recalled that abnormal increases in the amount of phosphates have been recorded by Ketchum and Keen (1948) following the red tide in the Florida sea water.

The general effects of animal exclusion caused by dinoflagellates have been discussed by Sproston (1949) and other authors. From the results available it is also fairly clear that the periods of diatom intensity in the plankton vary very much in the various sectors of the Indian coast. The results at Waltair are given by Ganapati and Murthy (1953, this Symposium). In Madras further south of Waltair, the diatom peak is in May with a secondary maximum from November to January, and the lean season for diatoms is from July to September (Menon, K. S. 1931). At Mandapam in the Gulf of Manaar the principal peak

period of diatoms is in May and there are other periods of maxima in February–March and again in August–November; the lean period is from December to January (Prasad, 1953 unpublished). At Trivandrum, the peak period is in May, but the lean period is in December (Menon, M.A.S. 1945). In Calicut on the other hand the peak period is in May, but there again secondary maxima are observed in January–February and again July–August (George, P. C. 1953). Investigations carried out in successive years have shown that there are quite often shifts in the periods of intensity and the occurrence of several minor peaks not usually observed in the colder waters. Further it is worthy of note that while a general peak can only be made out from the total number of various species, there are varying individual peaks for several species even in months other than in the collective peak periods. This has been specially brought out by detailed work on diatoms carried out at West Hill by Subrahmanyan (Unpublished). These results would indicate that the problems of diatom production and the subsequent effects of grazing by the zoo-plankton are much more complex in warmer waters where the phytoplankton and zoo-plankton maxima are not produced by any one or two species but by a large variety of species having varying periods of maxima and minima. It has to be ascertained to what extent the individual maxima of the various species are caused by physico-chemical factors or whether they are purely caused by biological sequences and also whether large scale planktonic outbursts of flagellates, *Noctiluca* and *Trichodesmium,* could be taken as indicative of abnormal turbulence, raising nutrients available in surface waters far above normal.

Seasonal Cycle of Nutrient Salts

Systematic studies on the distribution and seasonal cycle of nutrient salts in the Indian coastal waters have been undertaken in recent years at the Central Marine Fisheries Research Station, Mandapam, South India. The data reported in this note were collected between 1948 and 1953 at selected inshore stations in the Arabian Sea (West Coast—off Calicut) and in the Bay of Bengal (East Coast—off Madras city and off Mandapam). The following tables give the average monthly concentrations of the nutrient salts—phosphates and nitrates—in the inshore waters on both the west and east coasts. The annual ranges for phosphates and nitrates in the English Channel have also been included in the tables to serve as a basis for comparison.

TABLE II

AVERAGE MONTHLY VALUES FOR PHOSPHATES IN FOUR PLACES IN S. INDIA (NERITIC WATERS)
PHOSPHATES EXPRESSED AS UG—AT P/L.

	(Bay of Bengal)			(Arabian Sea)	
	Off Madras City 1948-49	Off Mandapam * 1950-53	Off Mandapam ** 1951-53	Off Calicut 1948-53	English Channel
January	0.50	0.20	0.20	0.48	Winter
February	0.40	0.22	0.21	0.40	maximum in
March	0.36	0.24	0.18	0.40	different
April	0.40	0.18	0.18	0.41	years:
May	0.45	0.18	0.17	0.70	0.47—0.70
June	1.00	0.26	0.25	0.89	
July	0.90	0.23	0.17	1.06	Summer
August	1.05	0.23	0.17	0.84	minimum in
September	0.70	0.22	0.21	0.85	different
October	0.48	0.18	0.21	0.72	years:
November	0.35	0.20	0.23	0.64	0.02—0.10
December	0.30	0.15	0.18	0.53	(Harvey, 1945)

* Gulf of Manaar.
** Palk Bay.

TABLE III

AVERAGE MONTHLY VALUES FOR NITRATES—
NITRATES EXPRESSED AS UG.—AT N/L.

	(Bay of Bengal)			(Arabian Sea)	
	Off Madras City 1948-49	Off Mandapam ** 1950-53	Off Mandapam * 1951-53	Off Calicut 1951-53	English Channel
January	2.0	2.9	4.0	5.6	Winter
February	1.1	3.2	3.2	8.3	maximum in
March	3.2	3.1	3.5	4.8	different
April	2.0	3.2	3.3	3.4	years:
May	Data not	2.4	2.9	16.3	6.0—7.0
June	available	2.0	3.7	10.6	
July	8.6	2.5	3.2	15.5	Summer
August	4.6	2.6	3.3	10.6	minimum in
September	2.8	2.1	3.8	2.4	different
October	3.0	2.7	3.4	3.5	years:
November	2.6	3.0	3.8	0.5	0.0
December	1.8	2.9	4.4	2.8	(Harvey, 1945).

* Gulf of Manaar.
** Palk Bay.

It will be seen from these tables that there are considerable variations in the distribution of nutrient salts in the waters of the two coasts and also in different areas on the same coast. In the waters of the Arabian Sea and in the Bay of Bengal off Madras city the phosphates are found to occur in very high concentrations. Distinct seasonal cycles of phosphates have been observed in the inshore waters of the Arabian Sea. In this area, the phosphate values are very high during the period of the Southwest monsoon, May to September. The nitrates are also high during the same period. It may thus be noted that during the Southwest monsoon, the surface waters off the west coast are replenished with nutrient salts to a considerable extent. The rate of replenishment also seems to be quite high. It is therefore, possible that the productivity, which depends a great deal on the rate of replenishment, is also high.

A comparison of the values of nutrient salts in the waters of the Arabian Sea with the range of concentrations reported for the waters of the English Channel shows that the total turnover of nutrient salts in the former area is somewhat higher than in the latter. If conditions such as temperature, light intensity, etc. are favourable, as is usually the case in the tropical waters, the total production of organic matter per unit area would appear to be higher in the waters of the Arabian Sea than in the English Channel. Although much more data are necessary, it seems safe to conclude that the production is at least of about the same order as is observed in most temperate waters.

The distribution of nutrients in the waters of the Bay of Bengal off Mandapam presents an entirely different picture. The level of nutrients in these waters is in general much lower than in the other areas. Seasonal variations in the concentrations of nutrients are also very small. Of the two areas studied near Mandapam there are differences in the amount of nutrients available at Palk Bay and in the Gulf of Manaar, the former generally showing slightly higher values. Studies on plankton show that likewise, Palk Bay appears to show a higher plankton production as compared with the Gulf of Manaar (Prasad, Unpublished). These require much closer study in relation to succession of organisms. The work so far carried out has only shown how difficult it is to form generalized conclusions even within adjacent areas.

Conclusion

The evidence brought forward and the views expressed at this symposium have certainly indicated the need for more intensive work on marine problems in any effort to open up new areas for fishing. An energetic and integrated programme on Oceanography and Fisheries in

tropical waters may well result in much information of value to dispel the belief prevalent among many that tropical sea fisheries cannot be developed because there are no fish in those waters, and which may pave the way for developing new food resources in the Indo-Pacific area.

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