

BIOLOGICAL AND OCEANOGRAPHIC DIFFERENCES BETWEEN THE ARABIAN SEA AND THE BAY OF BENGAL AS OBSERVED FROM THE INDIAN REGION

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ABSTRACT

The paper presents some of the important differences in the oceanographical and biological conditions in the waters of the Arabian Sea and the Bay of Bengal along the Indian coasts. In discussing the biological variability of the two environments from the point of view of fishery productivity, attention is particularly drawn to the extremely complex nature of the oil sardine and mackerel fisheries, especially along the west coast of India, which accounts for the bulk of the fish landings. An attempt is being made to provide a suitable explanation for this on the basis of the nutrient distribution pattern associated with the occurrence of seasonal 'upwelling'. It is also pointed out that the 'upwelling' processes along the west coast of India are also of a complex nature and the forces leading to this are yet to be properly understood. Some comparison is drawn between the conditions on the south-west coast of India and some of the classical upwelling regions of the world, particularly with reference to two important features, namely, formation and disappearance of temporary banks of mud and the occurrence of special planktonic blooms often leading to mass mortality of fish.

INTRODUCTION

FOR several years past the differences in the availability of fish on the west coast (or Arabian Sea Coast) and on the east coast (or the Bay of Bengal Coast) of India, has been quite a puzzling feature in India's sea-fish production. The fact that the coast between Bombay and Cochin accounted for heavy fish landings has been known for several centuries, but only during the past 15 years or so, during which the fisheries statistical system has been slowly evolved, has it been possible to establish that nearly 75% of Indian sea-fish production out of a total annual production of 700-900 thousand tons (Table I) come from the west coast of India and even within this coastline

the strip between Quilon in South, and Ratnagiri in the North accounted for the bulk of the catch, the main components of this neritic-pelagic fishery being the Indian Mackerel, *Rastrelliger kanagurta*, the Malabar Sardine, *Sardinella longiceps* and related *Clupeoids*, the sole, *Cynoglossus semifasciatus* and the penaeid prawns of several species.

TABLE I

*Showing the landings of oil sardine, mackerel and sole on the west coast of India during a 16-year period, 1950-1965**

[Landings in Metric Tons (Tonnes)].

Year	Oil sardine	Mackerel	Malabar sole
1950	34,420	86,736	..
1951	17,240	1,03,574	..
1952	13,895	77,295	..
1953	51,831	69,597	..
1954	33,952	27,892	1,657*
1955	30,447	21,848	5,507*
1956	7,412	15,023	9,122
1957	1,91,469	86,741	3,687
1958	1,23,282	1,23,282	12,856
1959	69,234	62,198	10,360
1960	1,89,016	1,33,655	14,103
1961	1,67,884	34,485	7,730
1962	1,10,299	29,103	17,644
1963	63,645	72,694	8,062
1964	2,74,307	19,097	4,691
1965	2,61,918	40,836	11,699

* Long tons.

TREND OF FISHERIES

To the student of geographical distribution who looks for individual species of fish, these present no features of interest, because they are all widely distributed Indo-Pacific species found along the coasts of India and adjoining countries. Both *Rastrelliger* and *Sardinella* occur on both sides of the Indian coast; but while small-scale or negligible landings of these are observed on the Bay of Bengal side, their yields run to a few hundred thousand tons on the south-west coast of India (Table I). The oil sardine which primarily feeds on phytoplankton forms a fishery which is subject to great fluctuations, an extreme instance being provided by its landing of 7,412 tons in 1956 m. and 274,307 m. tons in 1964. The mackerel landings were likewise variable during the past 14 years — on an average, about 60,000 m. tons with higher limits of 1,34,000 m. tons. From the Bay of Bengal side, on the other hand, the total yields in the case of both the fisheries have hardly exceeded 5,000 m. tons and in most of the years they form a very small component of the fish catches of the east coast of India, which themselves are very low by comparison with the west coast catches. A year-to-year comparison of the catch per unit of effort in the two regions is given in Table II.

TABLE II

Comparative figures of catch of fish per unit of effort for the east and west coasts of India in different years†
Catch/Unit Effort (in kg.)

Year	East coast	West coast
1954	0.61	3.18
1955	0.67	2.85
1956	0.92	2.95
1957	0.95	3.59
1958	0.85	3.19
1959	0.95	3.36
1960	1.30	6.75
1961	1.55	4.88
1962	1.27	5.06
1963	1.66	4.94

Unit Effort = Man-hour

† Source: Central Marine Fisheries Research Institute, Mandapam.

The causes of the fluctuations in these fisheries have been engaging the attention of the fishery workers in this country for quite some time and despite years of research in this direction, it has not yet been possible to arrive at a satisfactory solution of this problem. A review of the situation up to 1953 appears in a paper by Panikkar and Jayaraman (1956), who have examined this problem with reference to the differences in the hydrological conditions of the waters along the two coasts. The data presented mainly relate to inshore regions where the physico-chemical features are subject to local conditions and the interactions of the various factors in these environments are, in general, of an extremely complex nature. Since the publication of the paper, more offshore cruises have been undertaken on research vessels like *Kalaya*, *Varuna* and *INS Kistna*, and data collected over a wider area have yielded more information on the oceanographic conditions in these regions, and provide the basis for a better comparison of the two environments.

OCEANOGRAPHIC FEATURES

In regard to the oceanography of the Arabian Sea and the Bay of Bengal, a number of papers have appeared in recent years giving us a more or less broad picture of the distribution of the main oceanic parameters, the pattern of circulation, current systems, etc. (Rama Sastry and Myrland, 1959; Ramamritham and Jayaraman, 1960; LaFond, 1957). It is a well-known fact that the circulation of waters in the northern Indian Ocean including its two arms, the Arabian Sea and the Bay of Bengal is very much influenced by the pattern of winds associated with the summer and winter monsoons. While the general circulation in the more oceanic areas conform to the wind pattern, the water movements nearer the Indian coasts are governed more by the physical features such as bottom topography, coastal configuration, etc. In general, along the west coast of India, there is prevalent a south to south-easterly surface current from February to September and north-westerly current from November to January. A similar surface drift is seen along the east coast of India also, but this drift has a north-easterly direction with an occasional easterly component between February and July, changing to south-westerly in the northern part of the coast and to southerly in the southern part during August-September, and continuing in the same direction up to the end of December. In January a weak westerly drift is observed. While all these drifts are known from pilot charts (1953, 1961; also data sheets of Netherlands Meteorological Institute, 1952) we have very little detailed information on these currents. What is interesting from our point of view is that there are considerable differences in the hydrological

properties of the waters along both the coasts—both seasonal and regional—associated with these water movements. It is not clear how far these differences could be directly attributed to these drifts. It is, however, considered necessary to present here some of the salient features in the various hydrological parameters in the waters along both the coasts, to provide the necessary background for discussions on the variability of the conditions in the two areas.

1. *Salinity*

In regard to the surface salinity in both the areas, it is seen that the Bay of Bengal waters are less saline than the waters of the Arabian Sea. The average values are 30–33‰ for the Bay of Bengal and 34–37‰ for the Arabian Sea. These differences are generally explained by the fact that there is considerable influx of freshwater in the Bay of Bengal owing to number of large river systems both on the east coast of India and the Burmese coast leading to the lowering of salinity of the waters of the Bay; while the absence of any such large river system on the west coast of India combined with the intrusion of waters of very high salinity from the northern Arabian Sea, the Persian Gulf and the Red Sea contribute to the high salinity of the Arabian Sea-waters. These are, no doubt, well established details; it would, however, be necessary to indicate that there are also less understood differences in the vertical circulation patterns in the two areas.

2. *Temperature*

(i) *Surface Temperature*.—In the Bay of Bengal, the surface temperatures normally range between 27° C and 29° C., except in shallow areas nearer the coast. The fluctuations are much wider along the Arabian Sea coast of India, the usual range being 23°–29° C.; the lowest temperatures are reached during the latter part of summer monsoon along the southern west coast and during November-January period along the northern west coast. North of Bombay, along 20° N., the surface temperature sometimes reaches a value of 21° C. during late November and early December (Jayaraman and Gogate, 1957).

(ii) *Vertical Distribution Pattern*.—Although a considerable volume of data have accumulated in recent years on the temperature distribution in the Bay of Bengal resulting from the IIOE cruises, details in regard to the vertical distribution of temperature have not yet been completely worked out for this region. The earlier information pertaining to this region is

mainly based on the work of LaFond and co-workers at the Andhra University, Waltair (LaFond, *loc. cit.*). Some broad features in the recent data are indicated by Jayaraman (1965). On the other hand, for the waters along the west coast of India, between Cape Comorin and Bombay, the patterns have been worked out fairly well and even data on seasonal variations in certain selected areas are also available. The two important aspects that should receive our attention, from the point of view of their application to the problem of variations in biological productivity, are: (i) the variations in the thickness of the isothermal or near isothermal upper mixed layer and (ii) the level of the 'thermocline' or the discontinuity layer. A comparison of these two regions shows that in the Bay of Bengal off the Indian coast, the thermocline level is usually below 50-55 metres, occasionally going down to 100-125 metre level, and except for a small part off the east central coast, the shelf waters are for most of the time isothermal or near isothermal; whereas off the west coast of India, the thermocline fluctuates a great deal, often showing a definite seasonal trend.

It has been found that during winter, off the south-west coast of India, the thermocline is usually found at 100-125 metres and during the stable period between the winter and summer monsoons, the thermocline level is usually 75-90 metres. With the progress of the summer monsoon there is a gradual "upward migration" of the thermocline reaching to 20-30 metres and even surfacing in some areas towards the later half of the summer monsoon and early post-monsoon. This is seen to be a regular feature every year. It is also seen that in the same period, the shelf is occupied with water, which is cold, dense and poorly oxygenated and also very rich in nutrients (Ramamritham and Jayaraman, *loc. cit.*). Based on these findings, it has been postulated that the season of late monsoon and early post-monsoon is the upwelling season along the west coast of India and all the interesting findings in regard to the rich biological and fishery productivity* have been attributed to this seasonal 'upwelling' along this coast.

UPWELLING AND NUTRIENTS

This upwelling along the south-west coast of India and its possible connection with the fisheries of the area is slowly emerging as a very complex series of events. With a view to understanding the mechanism of this apparently complex phenomenon along this coast and to work out the role of the various

* A detailed study of zooplankton volumes by Prasad (1966 unpublished) has brought clear evidence of the much higher rate of plankton production in the Arabian Sea coastal waters than in most other regions of the Indian Ocean.

contributing factors, investigations have been carried out on the distribution of temperature, salinity, dissolved oxygen and the nutrient salts, particularly phosphates in the different regions along the west coast and along different sections normal to the coast covering both the inshore and offshore regions. The present indications are that "upwelling" is prevalent along the coast between 7° N. and 16° N. latitudes and the period is usually from August to early October. During this period it is observed that dissolved oxygen occurs in concentrations as low as 0.5 ml./l. below 20 metres. The phosphate occurs in very high concentrations in the entire water column over the shelf. In the nearshore areas off Calicut (depth 10 metres), the surface phosphate concentrations reach a figure of 1.94 mg.—at P/m³ while at the bottom the values are as high as 2.74 mg.—at P/m³ (Subrahmanyam, 1959). Recently Reddy and Sankaranarayanan (under publication) have found, in course of their studies on the vertical distribution of nutrients (phosphate, silicate and nitrates) along the west coast of India between Quilon and Ratnagiri, there is considerable enrichment of nearshore waters during the period of summer monsoon and early post-monsoon, while after mid-October up to the end of December the values become quite low.

One of the most noteworthy features in the distribution of phosphate in the coastal and nearshore waters off the south-west coast of India is the direct correlation between high concentration of phosphate and a rich crop of phytoplankton during the monsoon months. This observation has been discussed in detail by Jayaraman and Seshappa (1957) who have advanced the view that the peculiar hydrographical conditions associated with the prevailing south-west monsoon is responsible for the rate of replenishment of nutrients far exceeding the rate of utilization. This again is stated to have been brought about in two ways, namely (i) by local regenerative processes and (ii) the influx of nutrient-rich water into this region. In regard to the local regeneration, the principal mechanism is bacterial action on the dead and decaying matter present in the bottom muds possibly associated with heavy mortality of the bottom animals (Seshappa, 1953). The mortality of the bottom animals may be due to the combination of two factors, intrusion of oxygen-low water at the bottom and prevalence of turbulent conditions. Since it is well known that conversion of organically-bound phosphorus into inorganic phosphate is an anaerobic process (Cviic, 1956) the main contributing factor for the prevalence of anaerobic conditions is the intrusion of oxygen-poor water into this region apparently due to upwelling. It may thus be seen that there are a number of factors contributing to the nutrient enrichment in this region, the main

factor being upwelling. It should be pointed here that, although LaFond and others in the course of their studies along the east coast of India have reported upwelling as a regular seasonal phenomenon in the central part of that coast, the waters there, in general, do not contain nutrients in such high concentrations as those along the west coast.

It is, however, to be mentioned that, in spite of so much supporting evidence for the upwelling along the west coast of India, particularly southern part of west coast (the main region of the sardine-mackerel fishery complex), the processes leading to upwelling in this region have not yet been clearly understood. A study of the wind pattern at this time of the year shows that winds prevalent are most unfavourable for upwelling to take place. The dominant winds are onshore and these winds would promote 'piling' of the surface waters on to the coast rather than upwelling. In other words, this is not the typical wind-induced upwelling usually observed in the classical upwelling regions of the world. It is possible that this upwelling is associated with the southerly coastal current prevalent along the west coast of India during this period of the year. A reference in this connection to the observations by Ryther and Menzel (1965) seems pertinent. According to these authors the factors causing upwelling along the Somali Arabian coasts are due to the prevalent Somali Current as well as the offshore winds. The main reason for this observation is that in this region upwelling is prevalent not only during the south-west monsoon months but also October-November when there is practically no wind at all, the current however being still strong. On the same analogy it is possible to state that along the south-west coast of India although the winds are not favourable, the upwelling might be due to the dynamical factors associated with the southerly current. A detailed study of this water movement, which has not so far been carried out, would provide the necessary answer.

MUD BANK FORMATION

There are, however, one or two factors which indicate a certain amount of similarity between the west coast of India and other classical upwelling regions of the world. For example, the regular occurrence of mud banks off the south-west coast of India during the closing phase of the south-west monsoon and their disappearance within a period of 4 to 6 weeks are features which are similar to the occurrence of temporary islands of fine mud in the Benguela upwelling region off the west coast of Africa as reported by Hart and Currie (1960). These authors have, however, stated that these islands

almost completely disappeared within 24 hours whereas the mud banks off the Indian coast remain for a longer duration. According to Ramasastry and Myrland (1959) the formation of the mud banks off the Kerala coast is associated with the upwelling of these waters. It should, however, be mentioned that the mud banks formation and disappearance is the result of a series of events and it would be difficult to isolate a single factor and show it as the main causative factor. More detailed studies on these mud banks are being planned and it is hoped that we shall be able to find the answer soon.

PLANKTON BLOOMS

The occurrence of sudden blooms of certain planktonic organisms off the west coast of India is another case of similarity with some of the classical upwelling areas. These occur as discoloured patches over vast areas along the coast and often heavy mortalities of fish are associated with the occurrence of these blooms (Bhimachar and George, 1950). The organisms responsible for these blooms are mostly the flagellates, *Noctiluca*, and *Hornellia* (Subrahmanyam, 1954) and also the blue-green alga, *Trichodesmium* sp. Recently Prakash and Sarma (1964) have reported several discoloured patches in the sea off Cochin as being caused by blooms of *Gonyaulax*.

CONCLUSION

It may thus be seen that the part of the Indian coast known to support a very rich fishery for the mackerel and the oil sardine is a region of great biological and oceanographical complexity, one might almost say, of biological instability. A thorough understanding of the various factors is the *sine qua non* for finding a satisfactory solution to the major problem of the differences in the fishery productivity of the west and east coasts of India.

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