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A CRITICAL STUDY ON THE BAD EFFECTS OF UPWELLED WATERS ON FISHERIES, AS EXEMPLIFIED BY THE SITUATION OF THE KERALA-KARNATAKA REGION OF THE WEST COAST OF INDIA

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ABSTRACT

The inter-seasonal oscillation of the deoxygenated layer off the Kerala-Karnataka Coast and its encroachment to shallower regions of the shelf due to upwelling and its effects on both demersal and pelagic fisheries of the region were studied in detail. The results in broad, indicated that the oxygen depletion worked out differently on pelagic and demersal groups of fishes stressing the need for studies of tolerance limits of different species of fishes for deoxygenation of waters and the toxic effects of bacteria on fishes, as upwelling areas are known for heavy bacterial loads.

INTRODUCTION

THE REGIONS of upwelling are well-known for their fertility and their consequent fish-production (Wooster *et al.*, 1967). However, the depleted conditions of dissolved oxygen on account of upwelling is generally believed to be the cause for reduction of fish catch especially pelagic, even though the surface, and sub-surface waters are enriched by nutrients uplifted in the process of upwelling.

Favourable conditions exist in the waters off southwest coast of India (Kerala-Karnataka region) for upwelling process during summer (pre-monsoon and monsoon), especially during monsoon (Sharma, 1968 ; Sastry and D'Souza 1972 ; Lathipha and Murty, 1978). Deoxygenated waters of the deeper layers creep-up towards shallower regions across the shelf. The oscillating conditions across the shelf of the deoxygenated waters in descrete seasons over the year and their influence on both pelagic and demersal fish landings were critically studied in the present paper.

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MATERIAL AND METHODS

UNDP/FAO Pelagic Fisheries Project had collected hydrographic data by organising a good number of systematic cruises conducted during the years 1971-1975 covering the southern and sotuhwestern coasts of India. The cruise-wise dissolved oxygen data presented in their reports numbei 3 and 16, (UNDP/FAO Pelagic Fisheries Project 1973, 1976) between Quilon in the South and Karwar in the North of the southwest coast of India (from 9°N to 15°N have been considered here. Treating arbitrarily 1 ml/1 of dissolved oxygen as index of upper limit of oxygen deficiency of water the depth at which this isoplith of low oxygens occurred has been determined in each of the, vertical sections. Selecting the three main seasons namely, monsoon (June to August/ September), post-monsoon (November to January) and pre-monsoon (March to May), the seasonal depths of locations of the 1 ml/1 isoplith of dissolved oxygen were determined for the four self-cross sections, Karwar, Kasaragod, Cochin and Quilon (Fig. 1). The catches of fishes from the same region (Kerala-Karnataka) and for the same period were taken from the quarterwise landings of the CMFRI fish catch records. The species considered among demersal fishes were elasmobranchs, catfishes, perches, soles, prawns and other crustaceans. Sardines, mackerel, ribbonfish, anchovies, tunnies, carangids, seerfishes, baracudas, hilsa, billfish and mullets were the pelagic fishes available in this area. It was the general case that oilsardine and mackerel constituted the major fisheries among the pelagic, predominated by oilsardine. (Fishery Resources Assessment Division, 1982, 1986). In the annual catches for the years under study, oilsardine contributed 59% and mackerel 26% of the pelagic catches and the rest of the species each contributed about 5% or even less. Hence, oilsardine and mackerel together were treated to represent pelagic fisheries from the area. Following a special technique (Murty, 1985), the quarterwise fish landings were converted into monthwise landings from which the seasonwise landings were prepared. The seasonal catch figures were expressed in percentage of the annual (all the three seasons put together) catches of the demersal and pelagic fisheries separately (Fig. 2).

Results and Discussion

Deoxygenation

It is clear from Fig. 1 that the deoxygenated waters were limited to the slope region beyond the shelf edge (below 100 m depth) during pre-monsoon and post-monsoon periods. During monsoon period the poorly aerated waters entered over the shelf region. The upslope of the 1 ml/1 isoplith of dissolved oxygen towards coast is a clear indication of upwelling during monsoon. The rate of upwelling is estimated generally from the time rate of ascent of upsloping isopliths of parameters of temperature, density or dissolved oxygen towards the coast, or from the temperature difference from the sea surface and a suitable depth within the Ekman layer. Many authors made estimations of upwelling rate in the shelf waters of the southwest coast of India. Treating the stable thermal conditions of winter as reference, a conservative estimate of the average rate of upwelling in the waters by middle of monsoon period was made as 35 cm/day by Murty (1981). By detailed studies of vertical sections of temperature and dissolved oxygen, Narayana Pillai (1982) found that upwelling in these waters ranged between 23 cm/day and 86 cm/ day. Johannessen *et al.* (1987) made an estimate of upwelling at the rate of 150 cm/ day. Longhurst and Wooster (1990) used the trends of pre-monsoon (March and April) sea level changes as an index of secular studies of remotely forced upwelling in these waters.

Unlike temperature, dissolved oxygen is a nonconservative property of sea water, due to biological and bacteriological interferences and this is especially true in the case of neritic waters. Therefore, it may be said that the parameter, dissolved oxygen, serves only as a rough index of upwelling. Coastal upwelling occurs largely within a few tens of kilometres (Wooster, 1978) from coast. From the tendency of isotherms to run parallel to the coast, Cushing (1971) observed that the boundary of the California upwelling ranged from 100 km to 200 km off shore. It may be inferred from Fig. 1 that upwelling occurred, in the northern region, Karwar, within 100 km from coast at a depth of about 100 m from sea surface, as indicated by the coincidence of locations at off shore of the 1 ml/1 isolines of oxygen during monsoon and pre-monsoon. It occurred from a little more far off distance and from more deeper waters in the middle (Kasaragod - Cochin) and southern (Quilon) regions. By comparing

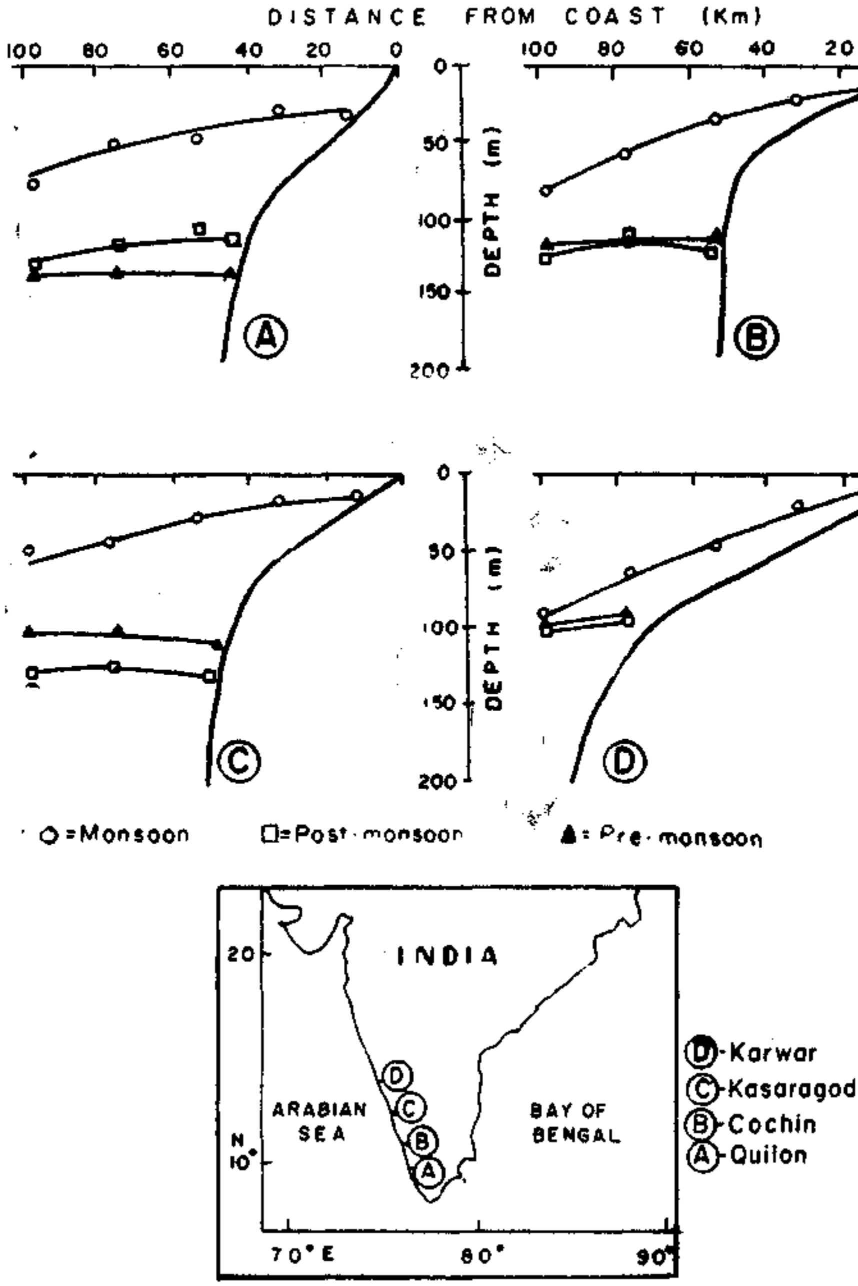

FIG. 1. Encroachment of deoxygenated water at different cross-shelf sections.

the rise of 1 ml/l isolines of dissolved oxygen during monsoon over the shelf in all the four places, we may infer that upwelling was weak and limited to narrow layer from the shelf bottom in the region of Karwar. In the middle and southern regions, upwelling was more intense and it infringed into a wider column of water. The influence of upwelling, perhaps through the process of diffusion, extended to as close to the coast as 10 m bathymetric contour in the northern region (Karwar), to 10-15 m depth in the middle region (between Kasaragod and Cochin) and only upto 30 m depth in the southern region (Quilon). Following a different method (summer minus winter dynamic depth variations), Lathipha and Murty (1978) obtained similar results on regional differences of intensity of upwelling along the southwest coast of India.

Fisheries

Fisheries operations are traditionally conducted with canoes (non-mechanised fishing boats) in the depth range of 15-25 m, while the mechanised fishing vessels operate in the depth range of about 26-60 m. However, fishing operations with mechanised vessels would not exceed 80 m bathymetric contour of the shelf bottom. There were no major changes in craft, gear or fishing effort from year to year, during the study period (1971-1975). Introduction of purse seines was only a later development (Jacob *et al.*, 1982) in Indian marine fisheries. Purse seines, 500-600 m in length and 50-60 m in depth with the mesh size 20-30 mm came into effect for pelagic fishing operations only in later half of 1979 in the waters of Cochin for the first time. Therefore, fishery-independent factors would have played a major role in affecting the fisheries.

Out of the total annual landings of the demersal fishes, more than half of them (56%) were captured during monsoon season (Fig. 2). The remaining fraction was shared more or less equally by the other two seasons. The catches of demersal fishes during monsoon period were the highest, when the poorly aerated waters occupied the entire range of fishing depths of bottom-trawl operations in the waters.

In this connection, it may be mentioned that Banse (1959) observed that the demersal fishes disappeared from a band of shelf bottom in the depth range of about 20-40 m in these waters in September-October, 1958. Comparing with dissolved oxygen close to the sea bed in the area, he attributed the disappearance of demersal fishes to the poorly aerated waters, even though Banse (1968) observed that on some occasions the trawl catch rates were higher in certain regions of poorly aerated waters. Further, he advanced a conception of poorly aerated 'band' of shelf region in the depth range of 20-40 m which he recommended to avoid for profitable trawling from either side of the band, but not within the band during the upwelling period, *i.e.*, monsoon season (Banse, 1959).

Such a band, if existed, required to be flanked by two equally valued isolines of dissolved oxygen on the shelf bed. It means that a layer of deoxygenated water has to be sandwiched between two aerated layers. The band thus imposes the condition that the dissolved oxygen values should go on increasing with depth from the lower border of the band, similar to the values maintaining their increase towards sea surface from the upper edge of the band. There was no report of increase of oxygen with depth at any level over the shelf of these waters in cruises conducted by FAO/UNDP Project vessels '*Rastrelliger*' and '*Sardinella*' or by Indo-Norwegian Project vessel R. V. '*Varuna*'. There is no scope for existence of such a 'band' of dissolved oxygen with a clear lower margin on the shelf bottom in these waters, resulting from upslope of isolines due to upwelling effect. However, it would be possible to come across 'patches' of oxygen-deficient water at certain locations of shelf floor due to intense bacterial decomposition of dead organic substances deposited at those locations.

The seasonality of pelagic fisheries presented a contrasting picture from that of the demersal. More than half (57%) of the annual catch of pelagic fishes was got during post-monsoon period, where as it was one-fourth (27%) during pre-monsoon and only one-sixth (16%) during monsoon period (Fig. 2). Analysis of oilsardine and mackerel catches (Virabhadra Rao, 1973) for the decade of years, 1956-1965, from Kerala-Karnataka Coast indicated that the monsoon or pre-monsoon catches constituted only about one-sixth of the post-monsoon catches of the same fishes. The fact that pelagic catch was lowest during monsoon and it improved tremendously by subsequent season (post-monsoon) might tempt one to believe that the retreat of deoxygenated water to the deeper depths beyond the shelf edge by post-monsoon favoured pelagic fishes with good column of aeration in the shelf waters from sea surface. But, the pelagic fish catch during pre-monsoon was almost equally poor as that of monsoon, even though the entire volume of water present in the shelf was free from deoxygenation during pre-monsoon period.

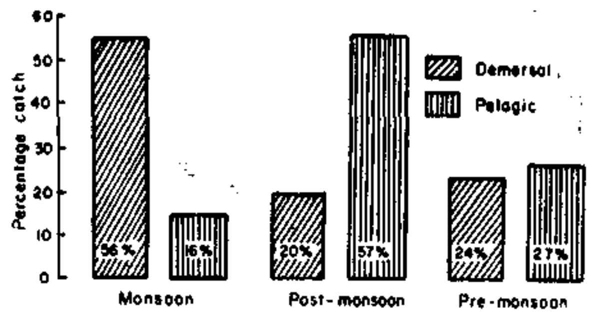

FIG. 2. Seasonal apportionment of fish catches (separate percentages for demersal and pelagic fisheries).

Longhurst and Wooster (1990) opined that any invasion of the shelf by water with low oxygen tension would tend to exclude oil-sardine along with other pelagic as well as demersal species from the coastal region. But the catches of demersal species were very high during monsoon, even though almost the entire bottom of the shelf was occupied by oxygen-deficient water. So, demersal species were not affected, at least at their fishable age, by the low oxygen water on the shelf bottom. Regarding pelagic fishes of which oilsardine have the lifespan of about 2 to 3 years (Antony Raja, 1969), if deoxygenation alone was the question of inconvenience for them, the pelagic fishes could have stayed in the water column overlying 1 ml/l isoline within the shelf itself where there was a plenty of water space with oxygen tension even during monsoon season. Therefore, the deleterious effects of deoxygenation during monsoon on pelagic fishery is only superficial. Other environmental parameters possibly with the combination of biotic factors might be responsible for the seasonal shift of the pelagic fisheries.

Thus, the inter-seasonal trends of bulk catches of fishes, whether they are demersal or pelagic, did not explicitly relate to the derogatory effects of oxygen deficiency in the waters. But, there were a number of instances on record that trawling near Cochin resulted in very poor catches, when the poorly oxygenated water was prevalent at the bottom (Banse, 1959 ; Sankaranarayanan and Qasim, 1969) and a few instances of mass mortality of fish in open parts of the Arabian Sea associated with oxygen depleted waters (Panikkar, 1969). In the abnormal cases, mass mortality was related being death by volcanism, by poisonous gases, chiefly H_2S (Margaretha Brongersmasanders, 1948) and by abrupt change in temperature and in salinity of the sea waters caused by passing cyclones (Nakai, 1939). All such instances are aperiodic and not prolonged. In the light of those correlating instances, it is hard to neglect the bad effects of deoxygenation on the fishes. Thus, some of the individual instances yielded results opposite to the interseasonal bulk results.

Inferences

It is a usual tendency to link up the dwindling catches of fish to the immediate or apparent cause of low oxygen in the waters. The contrasting seasonal response of demersal and pelagic fisheries for the shelf-inundated poorly aerated waters stresses the need for determining tolerance limits of the concerned species for low oxygen by conducting physiological and behavioural studies of fishes by simulated experiments under controlled conditions from board research vessels.

The real reason for dwindling catches may perhaps be sought in the toxic effects of bacterial load which is predominant in upwelling areas. It is therefore necessary to be cautious in interpreting the fluctuations of fisheries to the effect of depletion of oxygen caused by upwelling. There is an urgent need for a systematic bacteriological study in the direction of their toxic influences on fishes, especially in case of mass mortality and enmass depletion of fishes from a particular region.

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