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OCEANOGRAPHY OF THE ARABIAN SEA WITH PARTICULAR REFERENCE TO THE SOUTHWEST MONSOON

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Abstract

The oceanographic conditions in the Arabian Sea during the southwest monsoon is discussed. The main features occurring during this monsoon period in the Arabian Sea is the coastal upwelling along the southwest coast of India, the intensity of which is highest in the region Cochin to Mangalore. The currents along the coast during this season is southward. This also the season when mud-banks are formed at certain places along the coast. The effect of upwelling on primary and secondary production is also discussed.

Introduction

The oceanographic features show maximum changes in their characteristics during the southwest monsoon season mostly in the Arabian Sea than in the Bay of Bengal. These features and their impact on the ecosystem is considered in this paper.

Water Movements and Circulation

Along the west coast of India from Ratnagiri to Kanyakumari, during the southwest monsoon, a strong southward drift (especially in the region Calicut-Karwar) is prominent in the upper layers (Ramamirtham and Rao, 1974). A northward counter flow exists around the lower boundary of the thermocline, the flow being comparatively weaker and discontinuous.

In the region off Cochin, vertical turbulence has been found during the monsoon and early monsoon (Ramamirtham and Jayaraman, 1961). In the northern regions of Maharashtra and Gujarat during the middle of June predominance of eddies is noticed. Two distinct zones of salinity with zonal boundary off Bombay presenting higher values in regions north of this boundary are noticed. Dissolved oxygen values are higher in the region north of this boundary with values 7 ml/l and more off Jamnagar (Bapat *et al.*, 1982).

Upwelling

In the region between Kanyakumari and Karwar upwelling is noticed with the onset of southwest monsoon with the temperature discontinuity layer at a shallower level of 20 m (Rao and Ramamirtham, 1976). During July and August, the surface mixed layer becomes more or less obliterated with temperature maximum declining to 26.5°C and the oxygen deficit layer migrating even upto the surface (Fig. 1), indicating the existence of the coastal upwelling. The maximum intensity of the upwelling is in the Calicut-Karwar region (Rama Sastry and Myrland, 1959; Rao and Ramamirtham, 1976; Ramamirtham and Rao, 1974). This feature extends throughout the region from Kanyakumari to Karwar though the intensity is very less in the region south of Quilon. It is also noticed that upwelling starts in the southern region first and then extends northwards with the progress of the southwest monsoon season. The nature of the coastline towards southeast helps this trend (Ramamirtham and Rao, 1974). The coastal southward drift, the prevailing winds and the subsequent divergence in the Arabian Sea are the causes of this upwelling.

The depth of the thermocline along the west coast does not exceed 150 m in any month of the year and it is deepest in the months of January - February and shallowest during the peak monsoon, indicating upwelling upto August after which the thermocline tilts downward indicating sinking, the intensity of which is more during November and December (Sharma, 1968).

The Ekmann transport inferred from the wind-induced currents for the seas around India indicated the possibility of upwelling along the west coast of India, as well as in the southeastern

and central area off the east coast of India during the summer transition and southwest monsoon periods (Murty, 1981).

Dissolved Oxygen and Nutrients

During upwelling which starts with the onset of southwest monsoon waters colder than 26°C is found below 5 m in the coastal regions between Cochin to Karwar where the intensity of upwelling is highest. The thermocline (temperature discontinuity layer) is brought to the upper layers especially along the continental shelf. The dissolved oxygen lower than 2.5 ml/l is found in the surface layers below 10 m; and the oxygen discontinuity layer is also brought to the surface. The dissolved oxygen minimum layer with 0.5 ml/l starts from 50-75 m depth downwards during this season along the coast due to upwelling.

A general increase in phosphate and silicate contents of the waters has been observed in the region from Kanyakumari to Cochin during the southwest monsoon period when upwelling is prevalent. An increasing trend in the nutrient content of the waters is observed from south to north in this region. The Cochin region shows higher values than the region south of Quilon which may be due to the higher intensity of upwelling off Cochin compared to the southern region. Uniformly higher reactive phosphate values have been noticed at the bottom over the shelf region. The vertical distribution of phosphate shows an increase in phosphate content with depth

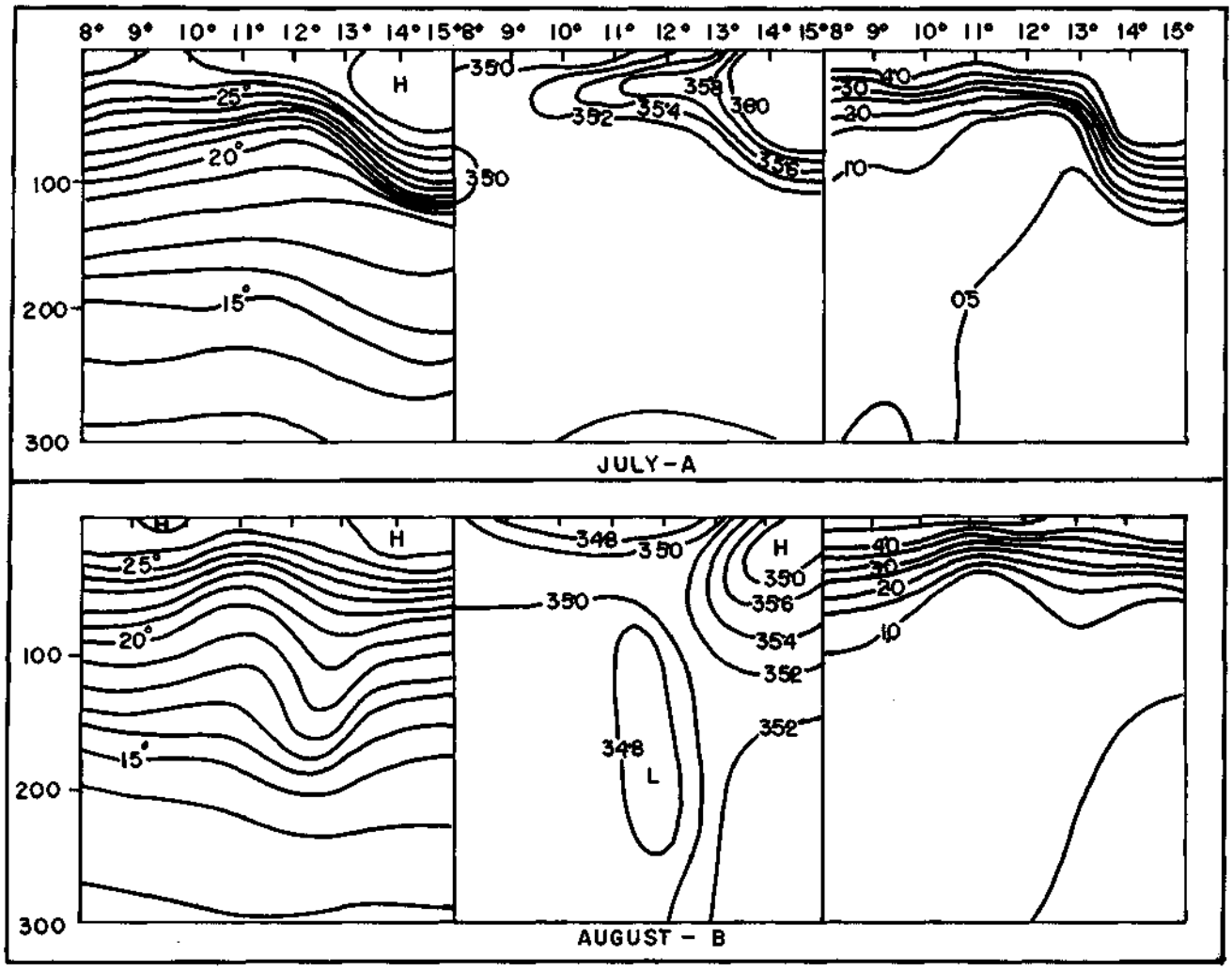

Fig. 1. Distribution of temperature (°C), salinity (‰) and dissolved oxygen (ml/l) in the meridional section during July and August (After Rao and Ramamirtham, 1976).

thus showing an inverse relationship with dissolved oxygen which decreases with increase of depth. The vertical distribution also shows an abrupt increase in the phosphate values within the thermocline layer (Rao, MS).

In the region off Cochin it is found that actual period of commencement of monsoon disturbances in the Arabian Sea could be assessed with an approximation of less than 10 days. The year 1985 noticed intermittence and failure in the southwest monsoon winds and rainfall from June to September. The monsoon characteristics and upwelling which are seen during June - July are found to disappear due to the failure of the southwest monsoon during the middle of August. This starts again with the revival of monsoon by early September. This type of intermittent upwelling following intermittency of occurrence of the SW monsoon was noticed in the year 1985 during the period June to September. The SW monsoon season also extended upto September during this year where as during the other years it was over by August. This type of intermittent upwelling affects the fishery of the region adversely (Ramamirtham, per. comm.).

Mud-Banks

Southwest monsoon season is the period when mud-banks are formed at some places along the southwest coast of India especially the Kerala Coast. This is a unique feature observed only in this region and has not been reported so far from any other place in the world. The source of mud for the Alleppey Mud-bank is the subterranean mud and the Vembanad Lake system provides the mud for this mud-bank (Rao *et al.*, 1980; Mathew *et al.*, 1981; Gopinathan *et al.*, 1984). "Mud-cones" or "Mud volcanoes" erupt in the weakest areas of the shore and in the intertidal zone. The eruption of these mud-cones does not occur every year, but during the year of occurrence of the mud-cones, it is found that the mud-bank remains over a period of 2-3 months from June to August whereas during the other years when no mud-cones occur the mud bank is present only for a short period of 2 to 3 weeks or even less. In the latter case the source of mud is the old mud brought to the region by the mud-cones erupted in any of the earlier years. The source of mud for the mud-bank between Parapanangadi and Tanur is the aggregation of coastal mud. The mud-banks at Chellanam-Manassery (Cochin Bar-mouth), Narakkal (Azhikode Bar-mouth), Valappad-Nattika (Chetwai River mouth), Elathur (Korapuzha River mouth), Quilandy (Kuttiyadi River mouth), Muzhippilangadi (Dharmadam River mouth), Kottikulam, Ajanur-N-Bella, Adakathubail (Chandragiri River mouth), Kumbala (Kumbala River mouth), Uppala (Uppala River mouth) and at Ullal (Netravati River mouth) are formed by the sediments and organic debris discharged from rivers and estuaries. Mud-bank at Vypeen (Cochin) is formed by the accumulation of mud resulting from dredging operation.

Mud-banks are maintained by the southwest monsoon with its westerly winds having more northerly components which cause the monsoon swells in the inshore region which along with the waves produce a constant thrust thereby preventing the mud from spreading into the sea. The monsoon swell also provides a continuous source of energy to keep the mud in suspension. The mud-banks formed on the southern side of the river/bar mouths remain only for a few days and then disappear.

The dissipation of the Alleppey Mud-bank takes place when the onshore thrust from the sea and from the backwater becomes reduced due to decline in the intensity of the monsoon. With this the heavy swells and waves which maintain the mud in suspension also declines in intensity and the southerly start reversing along the coast. The continued effect of the decline in shoreward winds, waves, swells and setting in of the northerly and onshore components of current help in the dissipation of loose mud in suspension and also in the settling down of the mud (Rao *et al.*, 1984; Mathew *et al.*, 1984).

The temperature and salinity in the mud-bank region are lowest compared to other seasons. The dissolved oxygen are lower during the monsoon season, lowest during the postmonsoon and highest during summer in the region of mud-bank. The reactive phosphate, silicate, nitrate and nitrite contents of the waters are highest in the region during the monsoon. These cooler waters being rich in nutrient content and low in salinity seem to favour primary production (Rao *et al.*, 1984). Primary production, surprisingly, is high only before and not during or after the formation of the mud bank. This is due to the turbidity of water in the region during the mud-bank season. Blooming

of *Noctiluca millaris* was observed at the time of dissipation of the mud-bank (Nair *et al.*, 1984).

The common belief that the mud-bank and fishery are interdependent, has been found to be incorrect. It is observed that when the fishing is almost suspended all along the coast, the mud-banks due to calmness in their environs provide ideal facilities for the fishermen to launch their craft. Direct observations have confirmed that bulk of the fish catch landed at the mud-bank area is from areas far away from the limits of the mud-bank. Taking advantage of the calm water, fishing units go in all directions in search of fish shoals. However, there have been occasions when good catches have also been obtained from within as well as outside the mud-bank areas. During this season a changing pattern of the fishery is seen (Regunathan *et al.*, 1984).

Phytoplankton in Relation to Upwelling

Upwelling along the southwest coast of India during the southwest monsoon has considerable influence on the coastal productivity. Along the west coast, maximum production of phytoplankton takes place during the southwest monsoon months after which there is a decline in the crop. The magnitude of the southwest monsoon bloom in the west coast waters is of a very high order surpassing those known from some of the most fertile waters of the world. Investigations on salinity, temperature and nutrients have shown that optimum conditions are obtained during southwest monsoon months, when the salinity of water falls from 35‰ or more to 30 - 31‰, the temperature decreases from 31-32°C to 23-25°C in the upper layers and the nutrients such as phosphate, nitrate and silicate become abundant due to upwelling and river discharges. These are the important factors for a high production of phytoplankton (Subrahmanyan, 1967).

Higher concentration of nutrients have been observed in the open part of the Arabian Sea at or near the base of the photic zone, especially at regions of upwelling with high production rate being recorded in the euphotic zone (Prasad, 1967).

Secondary Production in Relation to Upwelling

The productive value of upwelling is found to be reflected in the abundance of the total zooplankton biomass. Temporal and spatial lag of occurrence of zooplankton with respect to upwelling is noticed. Upwelling and plankton production are earlier in the southern regions of the coastline along the west coast then in the northern one (Murty, MS). Correlation of oceanographic features with zooplankton biomass and abundance of fish eggs and larvae (David Raj and Ramamirtham, 1981) shows that the continental shelf region along the southwest coast is markedly richer than the offshore regions as far as plankton biomass is concerned. The peak of plankton biomass is observed during peak southwest monsoon and postmonsoon periods, that is during and after upwelling, while the abundance of fish eggs and larvae shows a different trend with peak during premonsoon months.

The intensity of southwest monsoon plays a role in the long term fluctuations of the Indian oilsardine fishery, the higher intensity being favorable for the fishery. There is a critical intensity of monsoon turning in favour of the pelagic fishery (Murty and Edelman, 1971).

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