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HYDROGRAPHICAL FEATURES OF THE CONTINENTAL SHELF WATERS OFF COCHIN DURING THE YEARS 1958 AND 1959

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INTRODUCTION

THE hydrographical features and the seasonal variations in the physical and chemical conditions of the shelf waters off Cochin form an interesting subject of study. In this region, as well as in other areas along this coast, the influence of the south-west monsoon is very profound while that of the north-east monsoon is at best indirect. The changes in the conditions of these waters from time to time more or less reflect the changing pattern in the climatic conditions. The main circulation in the Arabian Sea results in the establishment of a surface current along this coast which reverses itself in the course of the year. This stream is southerly (i.e., towards south) when the circulation in the open part of the Arabian Sea is clockwise and northerly when the circulation is counter-clockwise. Associated with these drifts are the upwelling and sinking along this coast. The existence of these phenomena has been pointed out earlier by Sastry and Myrland (1960). In a preliminary analysis of the wind data during the period when upwelling is in evidence Jayaraman (1959) has pointed out that the prevailing winds are somewhat favourable for upwelling to take place, while Banse (1959) has regarded the prevailing current system and not the wind to be the main cause of the upwelling. It is not, however, the purpose of the present paper to discuss in detail the possible causes for upwelling or sinking along this coast, but it is intended to indicate that these various phenomena and the associated water movements could provide an explanation for the hydrographical features and their seasonal variations in the shelf waters along this coast. The interest is all the greater because Banse has shown that the demersal fisheries along this coast are fully dependent upon the prevailing hydrographic conditions.

COLLECTION OF DATA

The data presented in this paper Were collected during the years 1958 and 1959 from a normal section off Cochin. The collections have not been very systematic during the active period of the south-west monsoon—June to August—as the rough weather prevented going out to sea often and only when fair weather prevailed, collections were possible. More systematic collections were obtained from September onwards, although in September and October we could work only shallow stations down to 50 metres. From November onwards a number of stations were worked on this section which included a few deep stations outside the continental shelf. The inclusion of the deeper stations in the study was prompted by the need -to know to what extent the deeper waters influence the conditions on the shelf.

RESULTS AND DISCUSSIONS

All the data have been analysed in detail and vertical sections for the various parameters have been drawn. These vertical profiles are meant to give a better and clearer representation of the conditions and permit drawing of broad generalizations for the purpose of characterizing the environment. These sections are shown in Figs. 1-8 and the values for dissolved oxygen given in the table below.

TABLE I

Vertical distribution of dissolved oxygen in ml/L at selected Stations off Cochin during the observational period

Depth in metres	Sept. 1958	Oct. 1958	Nov. 1958	Dec. 1958	Jan. 1939	Apr. 1959	May J959
0	4.95	3.95	4.40	4.70	5.00	4.05	4.25
10	3.20	2.35	4.40	4.30	—	3.70	4.25
20	0.25	0.75	4.40	4.65	5.05	3,80	4.25
30	0.05	0.70	4.45	4.50	5.00	3.40	4.10
50			3.85	4.55	5.30	3.25	4.10
75			2.40	4.50	3.90	3.30	2.80
100			2.30	4.10	2.60	2.80	1.80
150			0.90	1.15	0.50	0.85	0.60
200			0.35	—	0.30	0.25	0,20
300			0.25	0.20	0.30	0.20	0.40
400			0.60	0.35	0.35	0.25	0.35
500			0.35	—	0.35	0.20	0.30

In presenting the data for purpose of discussion, we have grouped them under different categories as follows :

1. The active period of the south-west monsoon*
2. The period when upwelling is in evidence,
3. The period of sinking or downwelling,
4. The period when the environment can be considered to be fairly stable, and
5. The pre-south-west monsoon period or the transition between stable conditions and rough conditions associated with the S.W. monsoon. This type of classification, although purely arbitrary, is preferable to discussing the data irionth-by-month as this would present a good comparative picture of the hydrographical conditions as influenced by these various phenomena,

1. *The active period of the South- West monsoon*

The months June and July and the earlier half of August can be considered to be the active period of the south-west monsoon in the area under investigation. From the available data there is an indication that the temperature and salinity both show a tendency to decrease from the high summer values of the waters.

2. *The period of upwelling*

From the middle of August the typical changes in the hydrographical conditions associated with upwelling are in evidence. A thin layer of about 10 metres from surface downwards is characterized by very low salinity, but below this low salinity layer, there is a very sharp increase in salinity and decrease in temperature. In the month of August it was possible to work only two stations, one a relatively shallow station of depth 25 metres (St. I) and the second (St. II) which is deeper and more offshore, the depth being 50 metres. The main characteristics at these two stations are indicated by the values given below.

	Surface		10 *metres*		20 *metres*	
	St. I	St. II	St. I	St. II	St. I	St. II
Temperature °C	« 26.12	26.65	24.01	26.43	23.84	24.25
Salinity %o	33.14	32.78	35.03	33.19	35.04	35.03
Dissolved Oxygen ml/L	6.10	5.00	1.90	5.35	0.90	1.65

It is clear from this set of values that the water at 20 metres level in the deeper station and that at 10 metre level in the shallower station has more or less the same characteristics. There is a clear indication that upwelling has commenced in this region by about the middle of August.

From the marked lowering of the surface temperature it appears that the upwelling has influenced the surface layers also ; but the influence in the salinity does not appear to be so marked. (See Figs. 1 & 5). It is probably because the influx of fresh water continues to dominate in the region. The freshets that pour into the backwaters and thence into the sea seem to extend at the surface as a tongue of low salinity water for a considerable distance from the coast. It may be seen that by the end of September ' upwelling' seems to have been well established along this coast and the waters that have occupied the shelf have almost all the characteristics of a typical upwelled water. The following are the main features.

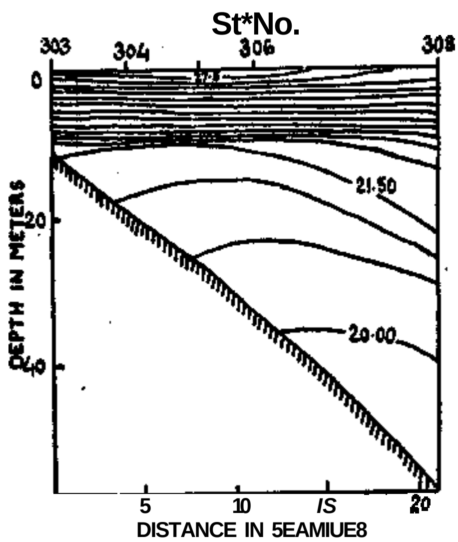

Fig. 1. Vertical distribution of temperature during upwelling—Contour Interval 0.5° C.

The temperature discontinuity seems to commence almost right from the surface. The thermal gradient is very sharp below 20 metres and except for a thin layer of 10 metres at the top, the entire shelf is pervaded by cold (below 22°C), highly saline and very poorly oxygenated water. The dissolved oxygen content is less than 0.5 ml/L below 10 metres and in some instances values as low as 0.2-0.1 ml/L are recorded. The surface layer is well oxygenated due to the stirring action of the prevailing winds, but this oxygen-rich layer stops short of 10 metres because the forces leading to upwelling appear to be fairly strong pushing up the dense, oxygen-poor waters. It could be seen from the data that these conditions persist till about the middle of October (Fig. 1).

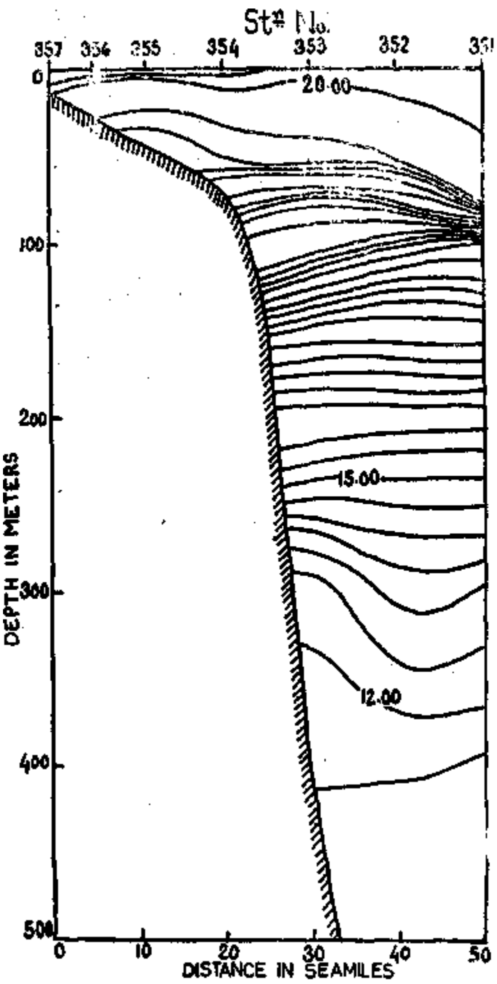

Fig. 2. Vertical distribution of temperature in the transition period between upwelling and sinking —Contour Interval 0.5°C.

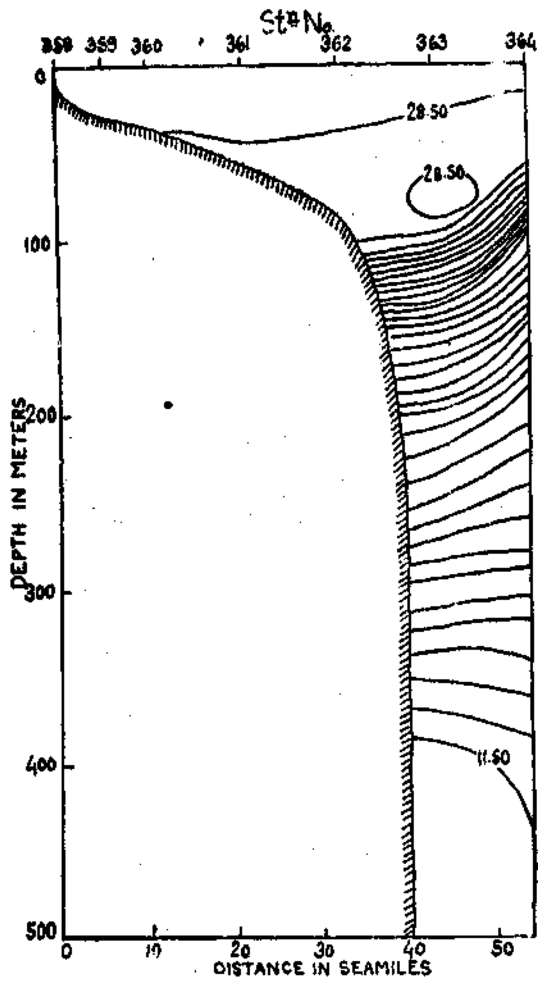

Fig. 3. Vertical distribution of temperature during the sinking period - Contour interval 0.5°C.

3. *The period of sinking or ' downwelliiig '*

By the end of October, the upwelling appears to have practically disappeared- The temperatures of the different layers have shown a definite increase. There is an increase of nearly 3°C in the surface temperature while at the sub-surface levels the increase has been between 5° and 7°C. The thermal discontinuity at the shallow levels has practically disappeared in the waters on the shelf by November and the entire, water column down to *50* metres has become typically isothermal, Thermocline is detectable only in the deeper waters at the edge of the shelf and beyond at about 75-100 meters. (See Fig. 2)

The entire water on the shelf has become highly saline by this time. The reasons are two-fold : firstly, upwelling has forced the highly saline waters right up to the surface and secondly, the fresh water influx has practically ceased. In the deeper waters a feebly developed salinity maximum is observed within the layer of temperature discontinuity. (Fig. 6)

It is inferred from an examination of the slope of the isotherms that there is considerable reduction in the strength of the southerly drift. This is probably a prelude to the reversal of the current which usually occurs at this time of the year.

With regard to dissolved oxygen, it may be stated that the oxygen-poor layer has tended to migrate downwards and by the end of November, a column of about 50 metres or even more on the entire shelf is saturated to the extent of 75-80 %.

The conditions during the month of December are much more clearly associated with the phenomenon of sinking or 'downwelling'. The thickness of the isothermal layer with the characteristic high temperature of 28°—28.5°C has increased considerably. The thermocline in the deeper waters is detectable at 100-120 metres and is seen to be very sharp. (Fig. 3)

A notable feature of the shelf waters during this period is that the salinity is low and the vertical distribution is more or less uniform all along the shelf. During December the salinity of the shelf waters varied only between 33 ‰ and 34 ‰ and during January between 32 ‰ and 33 ‰. Just outside the shelf there is a sudden increase in salinity. A well defined salinity maximum—35.8—36.0 ‰ is observed within a tongue of high saline water at the thermocline in the deeper waters beyond the shelf; but this water, in view of its high density, stops short of the continental slope or may be losing its identity on the shelf. The intensity of sinking or convergence is not known with any degree of certainty. It is however possible that, associated with this convergence there is a bottom run-off down the continental slope probably similar to the phenomenon of 'Cascading' described by Cooper and Vaux (1949).

A clear idea of the presence of sinking at this season can be gained from the slope of the isotherms. It is also seen that the northerly drift has by now gained in strength and this movement of the water is detectable down to even 100 metres as in the case of the southerly drift. (See Fig. 3)

With regard to dissolved oxygen, the shelf waters are seen to be completely well oxygenated. Beyond the shelf, oxygen-minimum was observed below 150 metres.

4. *The period of stable conditions*

This period (March & April) is characterized by a more or less complete absence of any water movement along the coast. There is a gradual warming up of the surface layers, the temperature varying between 29.5°C and 30.5°C. A fairly sharp thermocline is present at 100 metres. (Fig. 4)

The salinity has also shown a definite increase and values higher than 34.0 ‰ are observed in the surface waters on the shelf. (Fig. 8)

There is not much difference in the salinities of inshore and offshore waters on the shelf and also beyond. In regard to vertical distribution, there is a definite

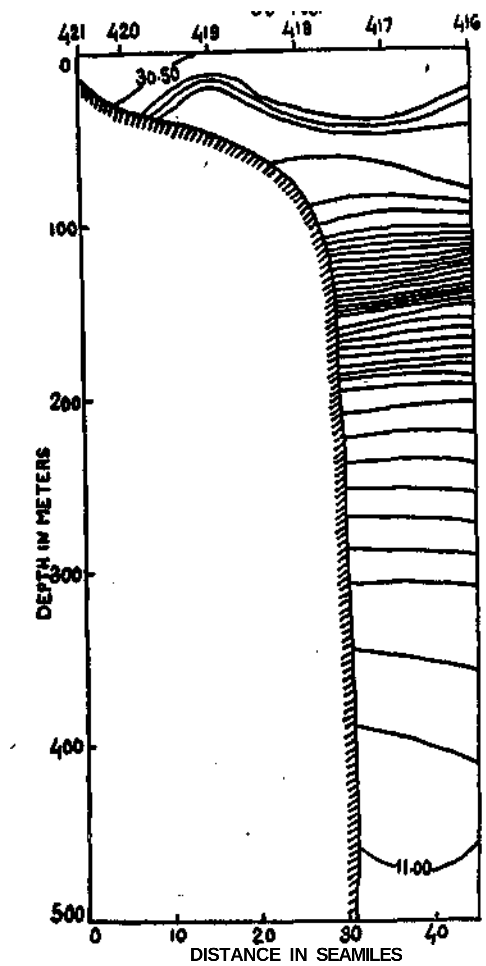

Fig. 4. Vertical distribution of temperature when stable conditions are prevailing—Contour interval 0.5°C.

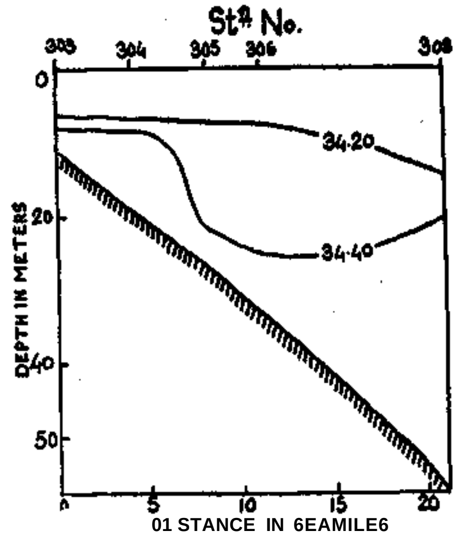

Fig. 5. Vertical distribution of salinity during upwelling.

positive gradient—i.e., increase of salinity with depth down to about 100 metres where a well-defined salinity maximum has developed. This is detectable only in the deeper waters beyond the shelf. It is clear that the waters are quite stable during this period of the year, the evidence for this is being provided by the typically horizontal character of the isotherms. (Fig. 4)

5. *Pre-south-west monsoon conditions*

During May there is a further warming up of the waters and the entire column of water on the shelf is tending to be isothermal. The surface temperature remains more or less at 31°C. The thermocline is still detectable only beyond the shelf at depths of 75-100 metres. By the end of May the conditions become unsettled, the upper and lower sub-surface waters lose most of their individual characteristics. The salinity maximum gets dissipated by the end of this period. This latter phenomenon is observed just before the onset of the monsoon winds,

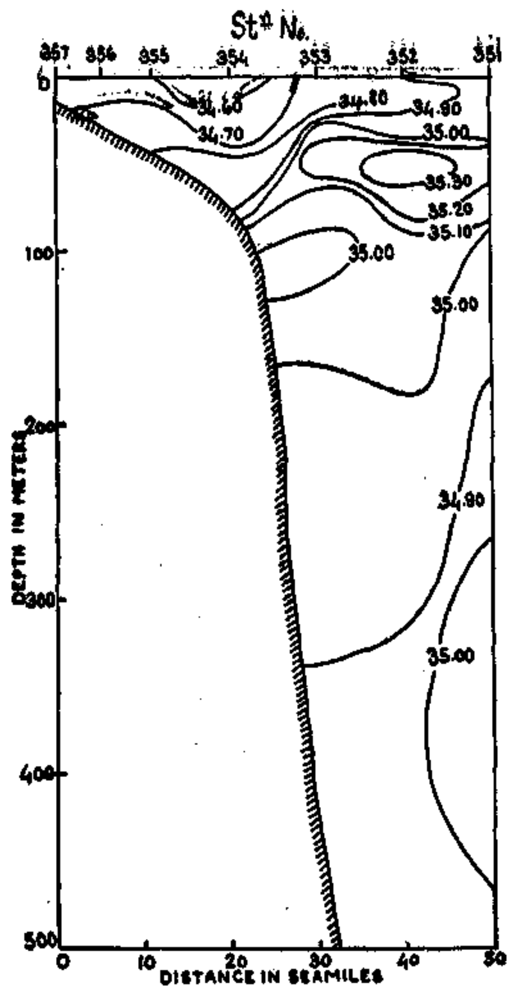

Fig. 6. Vertical distribution of salinity during transition period between upwelling and sinking.

SUMMARY

A descriptive account of the hydrographical conditions of the waters on the continental shelf off Cochin during the years 1958 and 1959 is presented. The year is arbitrarily divided into 5 seasons depending upon the characteristic changes in the climatic as well as hydrographical conditions and these are termed as: (1) Active period of the south-west monsoon comprising mainly the months June & July and early part of August, (2) the upwelling period comprising late August,

September and October, (3) the period of sinking—November to February, (4) stable summer conditions—March and April, and (5) pre-south-west monsoon—

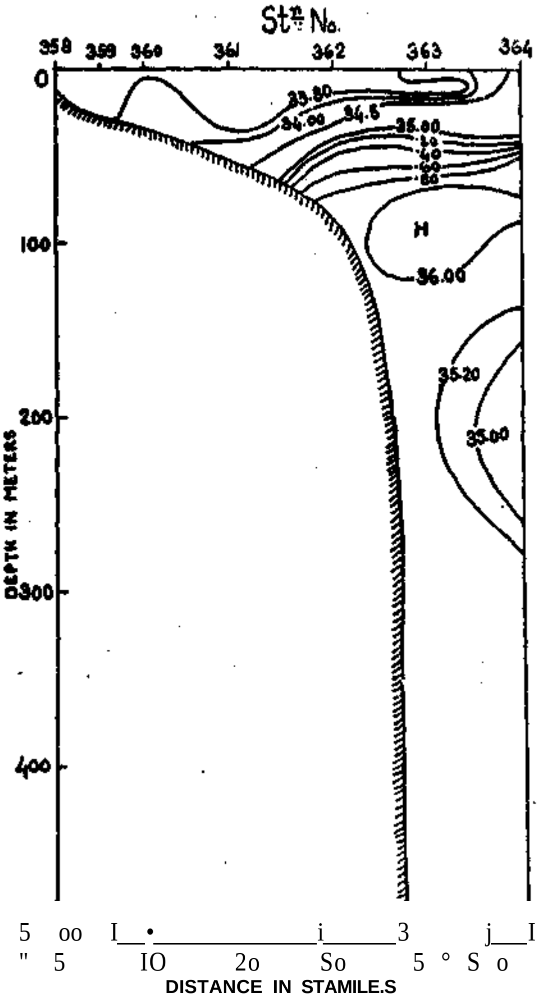

Fig. 7. Vertical distribution of [salinity during sinking period.

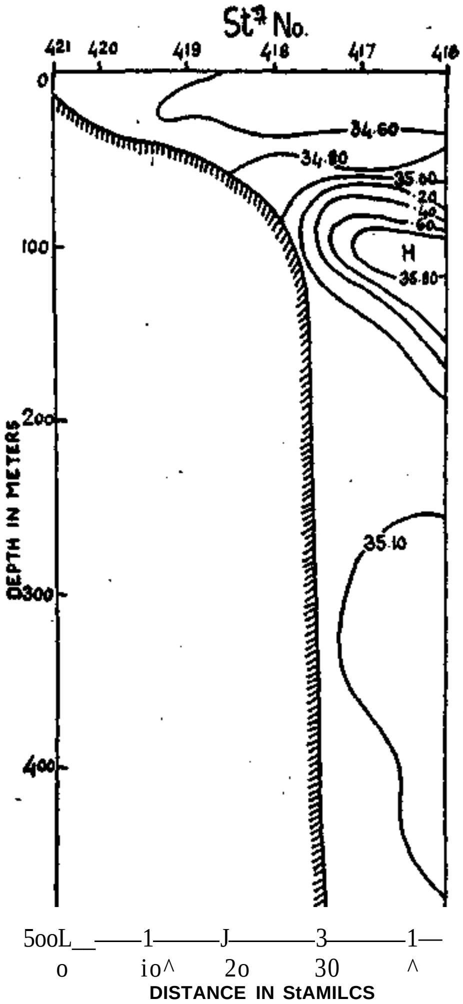

Fig. 8. Vertical distribution of salinity, when stable conditions are prevailing.

May. The factors such as temperature, salinity and oxygen content show typical seasonal variations associated with the variations in the general conditions of the environment.

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