Journal of the Marine Biological Association of India

ABBREVIATION : *J. Mar. biol. Ass. India*

VOL. X December 1968 No. 2

STUDIES ON SEA-WATER OFF THE NORTH KANARA COAST

By A. NOBLE

Central Marine Fisheries Research Institute

STUDIES on sea-water are important in fisheries research as the conditions in the sea play major roles in the availability of the basic producers and suppliers to the food chain in the sea and the fish itself, and yet these studies on our inshore waters are limited and scattered. The temperature, salinity, pH, dissolved oxygen, and the nutrient salts like dissolved inorganic phosphates, nitrites and silicates of the sea-water along the North Kanara Coast observed from January 1960 to December 1964 constitute this report. Ramamurthy (1963) reports about the studies he made here during 1954-58.

MATERIAL AND METHODS

The water samples were collected at surface between 6.00 and 7.00 a.m. from 4 fixed stations in the inshore area within a depth of 7 to 11 m off Karwar, Chendia, Ankola and Kumta, the latter 3 of which are 10, 32 and 64 km respectively south of Karwar (Fig. 1). Regular fortnightly sampling was made at Chendia, Ankola and Kumta. At Karwar the fortnightly collections were taken up to September 1962, and from October onwards collections were made twice in a week. The temperature readings were made *in situ* and other characters were studied at the laboratory. The pH was determined by a Lovibond Comparator using Thymol Blue and Phenol Red as indicators, the latter being used during the rainy season. The salinity was determined by Mohr's method using sea-water from Copenhagen as the standard. Dissolved oxygen was studied by Winkler's method. The inorganic phosphates, nitrites and silicates were estimated after Robinson and Thompson (1948 a, b & c) using Nessler tubes for colour comparison.

OBSERVATIONS

Temperature : The temperature is at its maximum in April or first part of May in the summer. It registers a fall by the end of May and generally reaches minimum during July-September (Figs. 2 and 9a) when the south west monsoon is most active. After the rains, it rises gradually and attains a peak during October-

January and afterwards registers another fall during December-February, when cooler weather prevails. From then on the temperature rises reaching high values in the following April-May, and this cycle is repeated every year.

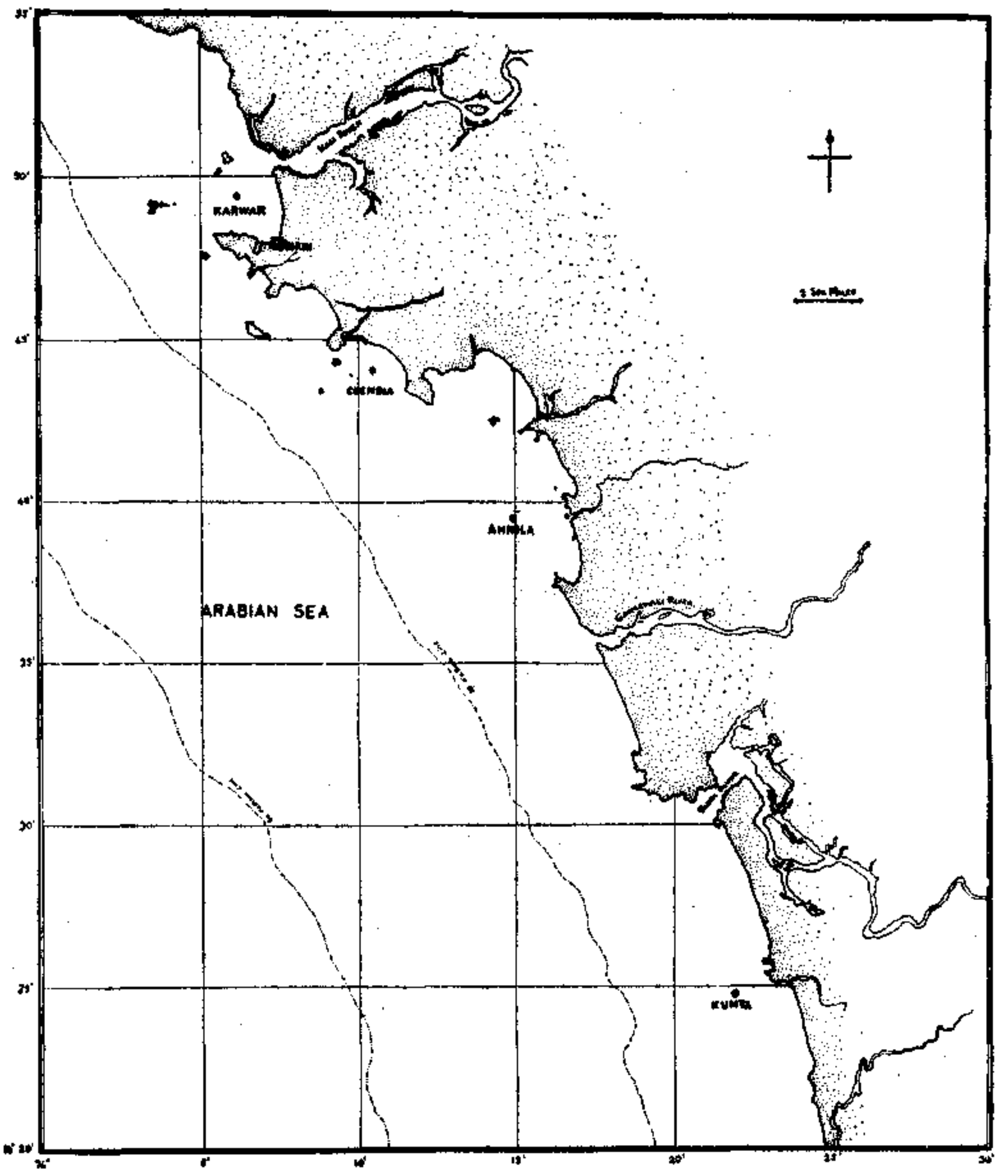

FIG. 1. North Kanara coast (Karwar-Kumta) from Admiralty Chart.

The peak occurring in summer months forms the primary and that of the post-monsoon months the secondary one. The fall during the monsoon forms the primary one and the secondary fall occurs in winter. However, the months in which these peaks and falls occur differ from year to year (Figs. 2 and 9a). In 1960 at Ankola there was no secondary peak and fall and instead the temperature steadily went up from the low values of September to the higher ones of the summer months.

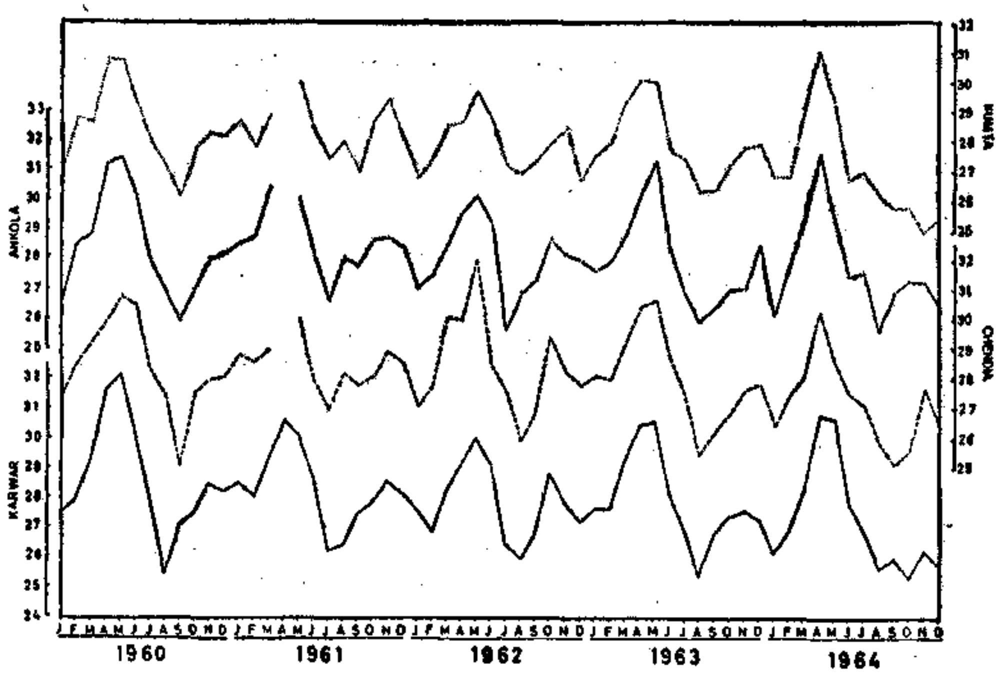

FIG. 2. Temperature °C (mean values).

Monthly mean temperatures for the 5-year-period (Table I) show the primary peak for the coast to occur in May, the primary fall in August, the secondary peak in November and the secondary fall in January. It can also be seen that the primary peak occurs earlier in south than north and the primary fall *vice versa*. The secondary peak and fall, however, occur almost simultaneously at all the places.

TABLE I

Monthly mean temperatures (in °C) for each centre as well as for the coast as a unit for the 5-year period.

—	*Karwar*	*Chendia*	*Ankola*	*Kumta*	*Coast*
January	27.50	27.55	27.23	27.43	27.43
February	27.52	28.05	28.13	27.81	27.88
March	28.89	28.11	29.21	28.91	29.03
April	30.53	30.15	30.65	30.18	30.38
May	30.72	30.39	30.51	29.97	30.40
June	28.84	28.62	28.70	28.21	28.59
July	26.92	27.48	26.98	26.96	27.20
August	25.81	26.61	26.73	26.96	26.53
September	26.85	26.22	26.92	26.58	26.64
October	27.38	27.49	27.75	27.51	27.53
November	27.74	28.08	27.88	27.80	27.88
December	27.36	27.71	27.92	27.32	27.58

The values of the primary and secondary peak show good range. The secondary fall generally does not reach the low level of the primary fall of the monsoon season. However, at Kumta (Fig. 2) the fall in January 1962 slightly exceeds the fall in August of that year.

The highest and the lowest temperature observed during the 5-year-period along the coast (Table II) were respectively 32.6 and 23.5°C and that they were observed in the northern part of it. The mean values for the maximum temperatures for the whole period under study were 31.64, 31.04, 31.22 and 30.66°C; and the mean minimum temperatures were 25.08, 25.16, 26.04 and 25.90°C respectively at Karwar, Chendia, Ankola and Kumta. The maximum values are thus higher in the north than in the south and the minimum values *vice versa*.

The range in temperature between the minimum and the maximum is more at Karwar, becoming smaller and smaller towards the southern stations, and the respective mean ranges for the 5-year period at Karwar, Chendia, Ankola and Kumta were 6.76, 5.88, 5.18 and 4.76°C. However, the 5-year mean values of the temperature, namely 28.00°C at Karwar, 28.09°C at Chendia, 28.18°C at Ankola and 27.98°C at Kumta show that the temperature along the coast is more or less uniform, though the maximum and the range decrease and the minimum increase towards the south.

The highest and the lowest temperature values vary from year to year. The minimum values at Karwar and Kumta (Table II) show an ascend in 1961 from the values of the previous year and then fall successively during the next 3 years. Though Chendia and Ankola exhibit slight changes in this curve the mean values for the coast as a whole, namely 25.68, 26.78, 25.85, 25.13 and 24.30°C for 1960, 1961, 1962, 1963 and 1964 respectively gave a comparable trend.

Another characteristic feature of the low temperature is that it usually occurs at first at Karwar and then at the southern stations. In 1960, it occurred at Karwar in August and at Chendia, Ankola and Kumta in September. In 1961, the lowest temperature recorded during July-August at Karwar was 26.2°C, first appearing in the earlier half of July and again in the latter half of August. The low temperature during July-August of the southern stations, namely 27.0°C at Chendia, 26.7°C at Ankola and 27.5°C at Kumta appeared in the first fortnight of July, second fortnight of July and second fortnight of July respectively. In 1962, the lowest temperature occurred at all stations by mid-August. The lowest temperature during 1963 appeared in the first half of August at Karwar and at Chendia, Ankola and Kumta in the latter half of the same month. In 1964, the lowest temperature at Karwar occurred in the first week of October. At Chendia it occurred in the second week of October and at Kumta by the end of November. At Ankola the temperature during October and November varied between 26.7-27.8°C and the lowest temperature, 25.7°C occurred in August.

The average yearly temperature (Fig. 10) shows a more or less uniform pattern of distribution at all places. It is comparatively more in 1960 and shows a declining trend during the 5 years under study. The mean values during 1960, 1961, 1962, 1963 and 1964 for the 4 places taken together were 28.46, 28.45, 28.08, 28.01 and 27.32°C respectively. According to this the values in 1960 and 1961 are almost equal and the temperature curve for the coast appears to be smoothly declining. From the average values it may be seen that 1960 was relatively the warmest and 1964 the coolest year during the entire period under study.

TABLE II

Maximum and minimum of the various hydrological factors, individual values.

Years	Temperature °C		Salinity ‰		pH		Oxygen ml/l		Phosphates μg at/l		Nitrites μg at/l		Silicates μg at/l	
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
1960	32.6	25.5	34.78	9.27	8.50	7.50	5.59	3.28	0.57	0.25	2.17	0.00	68.97	1.70
1961	32.0	26.2	35.39	0.77	8.40	6.90	5.59	3.81	0.56	0.27	1.09	0.00	149.25	2.10
1962	31.3	25.3	35.85	2.09	8.50	7.30	5.41	3.56	4.17	0.30	5.00	0.00	142.86	3.65
1963	31.3	24.4	35.42	2.80	8.45	7.35	5.34	3.10	1.10	0.22	5.86	0.00	95.24	3.25
1964	32.0	24.0	36.82	3.38	8.40	7.35	5.66	2.96	2.17	0.22	8.33	0.00	76.30	3.60
1960	31.2	25.0	33.82	19.11	8.60	8.10	5.66	3.11	0.65	0.27	1.32	0.00	53.33	1.50
1961	30.0*	27.0	35.40	10.72	8.50	8.10	5.27	2.96	0.62	0.27	2.94	0.00	59.70	2.20
1962	32.0	25.1	36.50	12.96	8.60	7.80	5.27	3.74	0.98	0.30	3.28	0.00	71.43	3.20
1963	31.0	25.2	35.77	14.56	8.40	8.00	4.99	2.39	1.87	0.25	4.55	0.00	62.50	3.85
1964	31.0	23.5	37.54	23.38	8.40	8.00	5.41	2.46	1.64	0.32	5.88	0.02	21.74	3.30
1960	31.6	26.0	33.84	19.33	8.50	8.10	5.23	3.11	0.57	0.31	2.78	0.00	43.48	1.80
1961	30.8*	26.7	34.88	5.46	8.40	7.90	5.34	2.92	0.64	0.31	1.92	0.00	105.26	2.20
1962	30.2	26.8	36.15	10.03	8.50	7.50	5.34	3.56	0.78	0.30	1.54	0.00	83.33	3.90
1963	31.8	25.0	35.67	14.42	8.40	8.10	4.99	2.89	1.37	0.28	2.27	0.00	62.50	3.95
1964	31.7	25.7	36.73	12.39	8.40	8.05	5.31	3.31	0.85	0.32	4.55	0.03	37.04	3.50
1960	31.4	26.2	34.22	22.56	8.50	8.20	5.11	3.10	0.62	0.32	1.47	0.00	35.71	1.20
1961	30.0*	27.2	35.26	2.97	8.50	6.90	5.13	3.28	0.61	0.33	1.25	0.00	74.07	2.20
1962	29.7	26.2	36.65	8.18	8.50	7.60	5.41	3.70	0.79	0.27	0.53	0.00	46.51	3.15
1963	30.4	25.9	35.43	19.43	8.40	8.00	5.02	3.45	1.33	0.28	3.45	0.00	52.63	4.25
1964	31.8	24.0	37.27	19.74	8.40	8.00	5.31	3.78	1.35	0.32	2.22	0.01	22.47	3.00

*There were no observations during April and first part of May 1961 when the temperature generally reaches its primary peak and the figures asterisked denote the highest values noticed at these places during the rest of the year, and it was in May, March and May at Chendia, Ankola and Kumta respectively.

As already cited earlier, the 5-year mean values of the temperature at Karwar, Chendia, Ankola and Kumta were respectively 28.00, 28.09, 28.18 and 27.98°C. The annual mean values for 1960 and 1961 at all these places are higher than the above ones (Fig. 10). The values at Chendia in 1962 and Kumta in 1963 are also higher. The average temperature for the whole period along the entire coast is found to be 28.09°C and yearly values given in the above paragraph likewise show it in the first 2 years to exceed and in the last 2 years to lag behind, with the middle year having a value almost equal. The temperature at Karwar and Kumta are a little lower than 5-year mean for the coast and that of Chendia same and Ankola slightly higher (Fig. 10).

Salinity : The salinity (Figs. 3 and 9a) attains high values during March-May and the averages reach a peak generally in April-May, except in 1962 when it appeared in March.

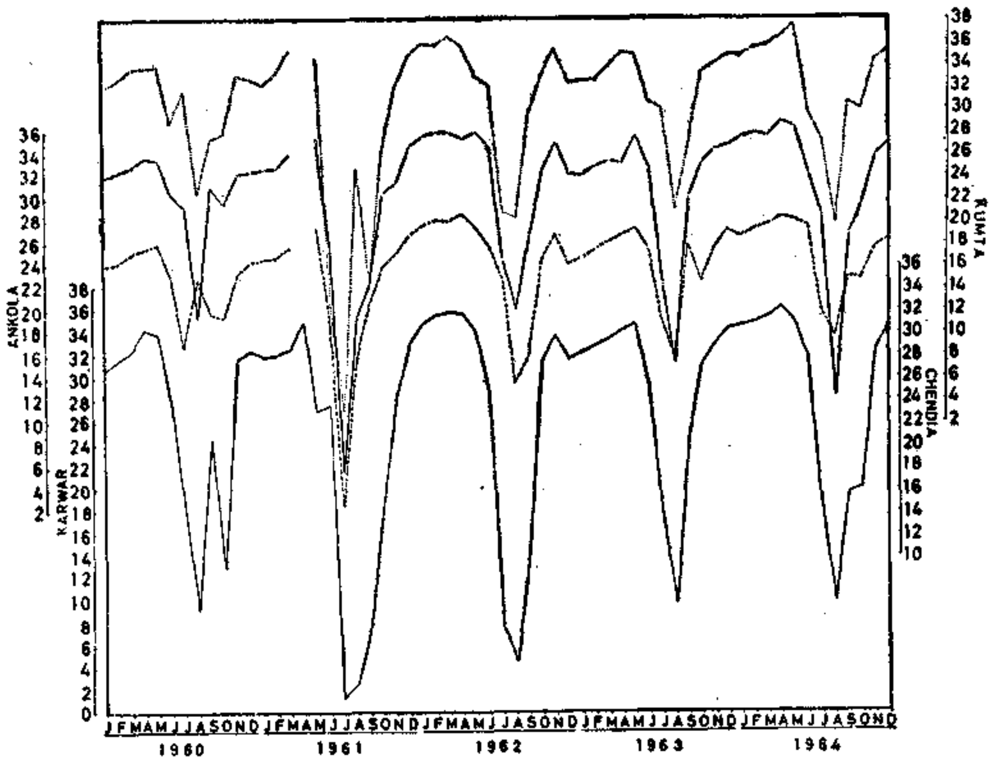

FIG. 3. Salinity ‰ (mean values).

The highest salinity recorded (Table II) along the entire coast for the years under study was 37.54 ‰. Average values of the maximum salinity at Karwar, Chendia, Ankola and Kumta for the 5-year period were respectively 35.65, 35.81, 35.45 and 35.77 ‰, and Chendia where the highest value was recorded appears to have high average values also. Similarly the annual maximum mean values for the coast as a whole, namely 34.17, 35.23, 36.29, 35.57 and 37.09 ‰ for 1960, 1961, 1962, 1963 and 1964 respectively, show 1964 as having relatively high maximum salinity and the highest for the coast was observed during this year.

From the peak of April-May which forms the primary one, the salinity falls steeply during July-August when there are heavy rains. The mean monthly values for the entire coast for the individual observation centres for the 5-year period (Table III) show the primary fall to occur in August except at Chendia where it happened to be in July. The peaks at Karwar, Chendia and Kumta as for the coast occur in April and at Ankola in May.

TABLE III

Monthly mean salinity values (in ‰) for each centre as well as for the coast as a unit for the 5-year period.

—	Karwar	Chendia	Ankola	Kumta	Coast
January	32.80	33.42	33.48	33.30	33.25
February	33.35	33.86	34.86	33.82	33.72
March	33.87	34.43	34.26	34.80	34.34
April	35.03	35.24	34.68	35.04	35.00
May	32.90	35.14	35.14	34.58	34.44
June	29.08	32.20	31.01	26.63	29.73
July	12.92	24.31	21.93	22.41	20.39
August	7.31	25.11	17.35	21.58	17.84
September	18.24	29.00	27.33	25.56	25.03
October	22.94	30.58	30.91	29.97	28.61
November	31.74	33.18	33.27	34.01	33.05
December	33.16	33.67	33.67	33.78	33.57

The primary fall in salinity was particularly conspicuous at Karwar and of all the minimum values along the coast, the lowest for each year was recorded here (Table II). The average value of the minimum at Karwar for the 5-year period was 3.66‰ as against 16.15, 12.33 and 14.58‰ at Chendia, Ankola and Kumta respectively. Chendia where high values in the maximum salinity were recorded appears to have higher values in the minimum also. The range of salinity at Karwar was great.

The minimum value was the lowest of all at Karwar in 1961. It was 0.77‰ and the rainfall during this year was comparatively heavy (Fig. 11). The values at other places the same year were also lower than in other years (Table II). The annual mean figures of the minimum values for the coast were 17.57, 4.98, 8.32, 12.80 and 14.74‰ respectively for 1960, 1961, 1962, 1963 and 1964.

In September, when the monsoon starts subsiding, the salinity rises. Before it reaches its primary peak of the succeeding year it shows a definite secondary peak and fall (Fig. 3) all along the coast during the period 1962-63. At other times they are either localised, insignificant or absent. The monthly mean values computed for the coast as a whole for each year (Fig. 9a) show the secondary peak to occur in November-December and the secondary fall in December-January. The secondary peak and fall during 1961-62 and 1963-64 are absent in this also, and for the coast as a whole they are entirely absent. Fig. 3, however, shows some variations with respect to individual observation centres.

The secondary fall is more common and well pronounced in the south than in the north. The range between the mean monthly values during the secondary peak and the secondary fall is always more at Kumta and in 1962-63 it appeared more pronounced and the highest range namely 3.07‰ was observed then. The succeeding primary peak in April 1963 did not attain as high a value as at the secondary peak of November 1962 (Fig. 3), the respective average values during these months being 34.88 and 35.23‰.

After the secondary fall, the salinity slowly and steadily goes up until it falls again in the next south-west monsoon season.

The yearly average salinity values (Fig. 10) give a uniform pattern at all the places. It showed a deep fall in 1961 from the values of the previous year. In the succeeding year it rose and then remained high during the rest of the period under observation. The annual mean values for the coast as a whole appear in the same way and they seem to be 29.69, 26.50, 30.79, 30.85 and 31.28‰ for 1960, 1961, 1962, 1963 and 1964 respectively. The mean values for the 5-year period at the different centres were 26.95, 31.58, 30.45 and 30.30‰ at Karwar, Chendia, Ankola and Kumta respectively. The annual mean values at these places in relation to the 5-year ones given above show (Fig.10) Karwar to resemble Chendia and Ankola to Kumta. At Karwar and Chendia the annual average values were lower even before 1961, whereas at Ankola and Kumta they fell only during this year. The mean for the entire coast for the 5-year period under observation was found to be only 29.82‰. The values at Karwar were lower throughout, whereas at Chendia, Ankola and Kumta the values during 1961 only were lower to that of Karwar.

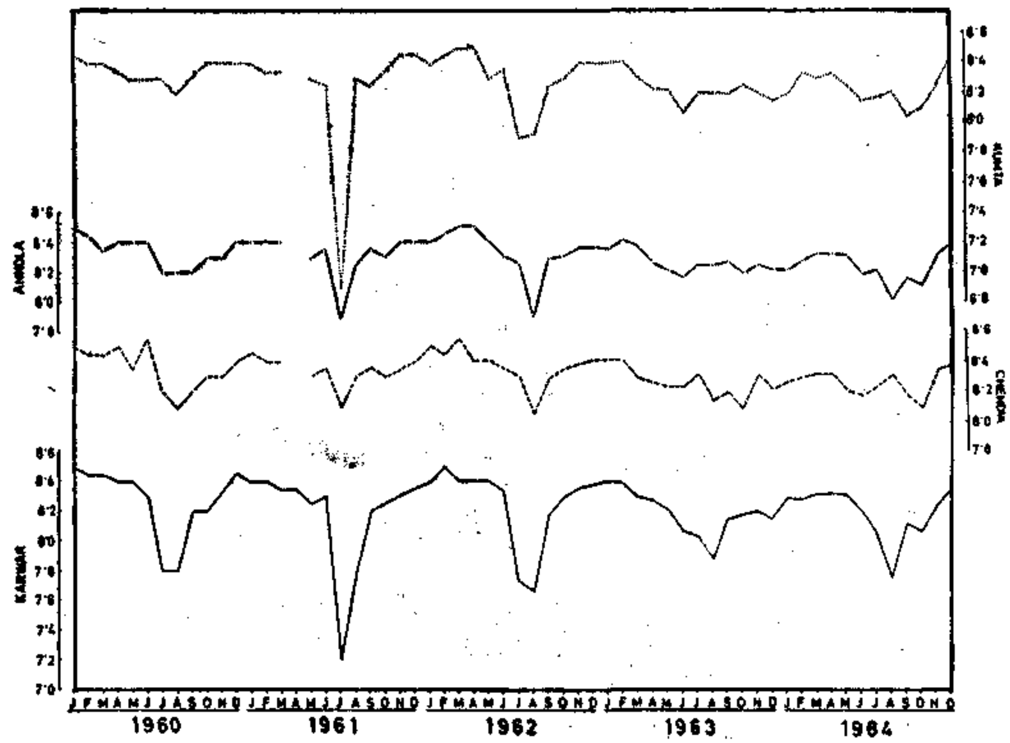

FIG. 4. pH (mean values).

The pH registers its fall (Fig. 4) and the minimum values (Table II) generally in July-August. The fall, however, extended to September 1960 at Ankola and it occurred in October 1963 and 1964 at Chendia, in June 1963 at Ankola and September 1964 at Kumta.

The lowest value observed during the 5-year-period for the coast as a whole was 6.9 and it occurred at Karwar and Kumta in the latter half of August 1961. The lowest values at Chendia and Ankola were 7.8 and 7.5 respectively, occurring in August 1962 at both the places.

From the fall the pH starts rising in the subsequent months and reaches a peak during December-March. At Kumta, it remained high during November 1962 to February 1963 without showing a definite peak.

After the peak the pH decreases and again registers the steep fall by July-August. The monthly mean values for the coast as a whole for each year (Fig. 9a), also show the falls to occur in July-August and the peaks in January-April. The monthly mean values for the coast for the 5-year period (Fig. 9a) show the drop in them in July and the peak in January. The 5-year mean values for each individual stations (Table IV) show that the falls occur in the north later than in the south and the peak *vice-versa*. At Karwar, however, the values during the fall and the peak remain for longer time.

TABLE IV

Monthly mean values of pH for each centre as well as for the coast as a unit for the 5-year period.

—	*Karwar*	*Chendia*	*Ankola*	*Kumta*	*Coast*
January	8.39	8.42	8.37	8.37	8.39
February	8.40	8.40	8.39	8.39	8.39
March	8.36	8.40	8.38	8.37	8.38
April	8.35	8.36	8.36	8.35	8.36
May	8.31	8.30	8.32	8.25	8.29
June	8.24	8.33	8.28	8.21	8.26
July	7.76	8.23	8.16	7.90	8.01
August	7.78	8.18	8.13	8.17	8.06
September	8.16	8.24	8.25	8.21	8.21
October	8.19	8.22	8.24	8.28	8.23
November	8.28	8.34	8.32	8.34	8.32
December	8.33	8.36	8.35	8.36	8.35

The rise and fall of pH values are gradual (Fig. 4). There was a sudden increase of pH at Chendia in June 1960, the value attained being 8.6. This is the highest recorded value for the whole coast during the years under study and it again appeared once during the peak at Chendia in March 1962. Generally the pH varied between 8.4 and 8.5 during the peak period. But in 1963-64, the values were only between 8.3 and 8.35.

An examination of the lowest value at different observation centres (Table II) shows that the fall and the subsequent range in pH are particularly deep at Karwar where it normally varied between 7.3 and 8.5. At Chendia, Ankola and Kumta the variation of pH is smaller, ranging only from 7.8 to 8.6, 7.5 to 8.5 and 7.6 to 8.5 respectively.

The annual mean values of pH (Fig. 10) from 1960 to 1962 at Chendia and Ankola are higher than their respective 5-year averages and in 1963 and 1964 they are lower. At Karwar and Kumta, there is a tendency for the annual mean values to increase and decrease alternately in successive years. The annual values for the coast taken together, namely 8.33, 8.26, 8.31, 8.23 and 8.22 for 1960, 1961, 1962, 1963 and 1964 respectively also show that the pH is comparatively low along the coast in 1964 and high in 1960.

The mean for the entire coast and period was 8.27. The 5-year annual mean values at Karwar and Kumta were lower than this and those at Chendia and Ankola higher (Fig. 10). The pH was the lowest at Karwar and the highest at Chendia. At Karwar it was above 8.27 in 1960 only, whereas at Kumta it went above that during 1960 and 1962. The values, on the other hand, at Chendia and Ankola were mostly higher than 8.27 and it came down of it only during 1963 and 1964.

Dissolved oxygen.: High concentrations of dissolved oxygen were met with in the sea-water during the rainy season, attaining a peak in June-September (mostly August). Immediately after the rains the oxygen registers a fall during September-November (mostly November). Between these occur another peak and fall generally during December-February (mostly February) and March-May (mostly May) respectively. The peak of December-February exceeded the peak of July-

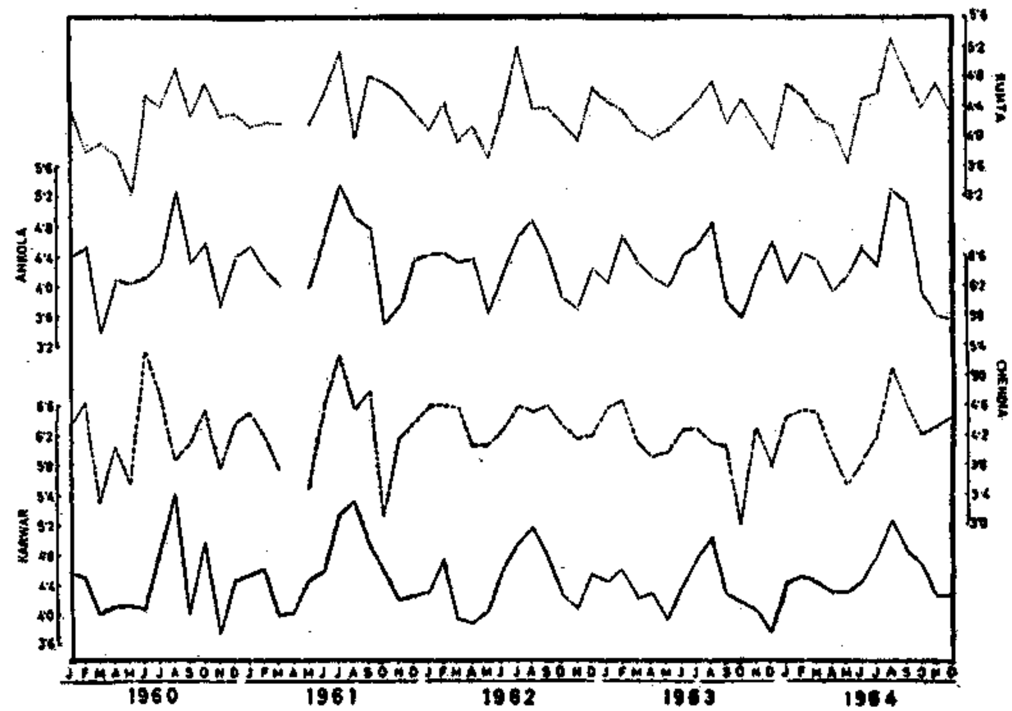

FIG. 5. Dissolved Oxygen ml/1 (mean values).

August only at Chendia twice during the 5 years of study (Fig. 5). The falls of March-May exceeded that of September-November more often and at more places.

The monthly average values during each year for the 4 places taken together (Fig. 9a) show the oxygen to peak first in July-August and then in January-February. The monthly mean values for the 5-year period at each place (Table V) also show this. The first fall according to this occurred in April-May (May for the coast) and the second fall in October-November (November for the coast). The first falls according to Fig. 9a occurred in March and May and the second in October-December.

TABLE V

Monthly mean values of dissolved oxygen (ml/l) for each centre as well as for the coast as a unit for the 5-year period.

—	*Karwar*	*Chendia*	*Ankola*	*Kumta*	*Coast*
January	4.44	4.58	4.27	4.37	4.39
February	4.58	4.52	4.43	4.28	4.45
March	4.12	4.04	4.07	4.09	4.08
April	4.11	3.99	4.12	4.01	4.06
May	4.17	3.72	3.95	3.82	3.92
June	4.41	4.45	4.36	4.48	4.42
July	4.93	4.56	4.61	4.77	4.72
August	5.31	4.42	5.04	4.72	4.87
September	4.58	4.41	4.47	4.51	4.49
October	4.53	3.83	3.87	4.51	4.18
November	4.06	4.13	3.78	4.34	4.08
December	4.25	4.23	4.21	4.30	4.25

The monthly mean values for the coast as a unit for all the years combined (Fig. 9a) show the peak that occurs in August as primary and that of February as secondary. The falls according to this in May exceed slightly over that of November. But as indirectly stated earlier the November falls exceed the May ones in certain years and places (see Table V also). The monthly mean values for the coast during 1960-64 (Table V), however, show the fall in May as primary and in November as secondary. The difference between these 2 falls is very little and as it is prone to change from place to place and from year to year it is not safe to generalise one as major and the other as minor. The highest and the lowest values recorded during this study along the coast were 5.66 ml/1 at Karwar in August 1964 and Chendia in June 1960, and 2.39 ml/1 at Chendia in October 1963 (Table II) respectively.

The annual mean values for the different centres are given in Fig. 10, and the fluctuations show more or less the same pattern at all the places. The annual mean values for the coast as a whole, namely 4.27, 4.42, 4.33, 4.23 and 4.40 ml/1 respectively for 1960, 1961, 1962, 1963 and 1964 endorse this; and show 1961 as having comparatively more oxygen and 1963 less. The average value of oxygen for the coast during 1960-64 (5 years) was 4.33 ml/1. The 5-year mean values at Karwar and Kumta were higher and those at Chendia and Ankola lower (Fig. 10). The 5-year mean values were 4.46, 4.24, 4.27 and 4.36 ml/1 at Karwar, Chendia, Ankola and Kumta respectively. Karwar has a high value and other places more or less equal though there appears a tendency for an increase towards the south. The mean minimum values at Karwar, Chendia, Ankola and Kumta, namely 3.37, 2.93, 3.16 and 3.46 ml/l respectively also give more or less a similar picture. The mean maximum values were 5.52, 5.32, 5.24 and 5.20 ml/l at Karwar, Chendia, Ankola and Kumta respectively and they show Karwar to have more oxygen; but the values, on the other hand, decrease at other places from north to south.

Dissolved inorganic phosphates : High concentrations of this nutrient salt in the sea-water occur during June-October. The actual month in which the peak occurs varies from year to year and differs (Fig. 6) among the observation centres during the same year. In the 2 southern stations there is a tendency for the peak to occur earlier, as they are found in June-September. The only occasion in which the peak appears in October at south is in 1961 at Ankola. The values fall and become generally low mostly in January but spread out from October to May. Sometimes at some places a sub-peak can clearly be noticed during February-April (Fig. 6). The falls preceding these are generally deeper but only slightly than the succeeding ones except on a few occasions as at Karwar, Ankola and Kumta in 1963. This second fall occurs generally during April-May.

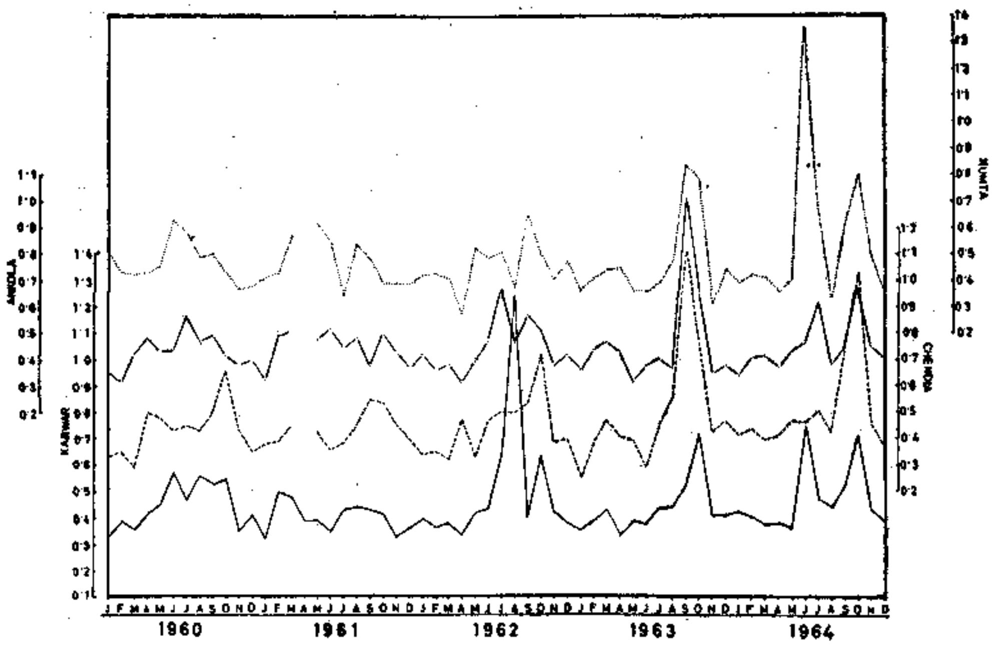

FIG. 6. Inorganic Phosphates $\mu g\ at/l$ (mean values).

The monthly mean values for the 5-year period for each place also show (Fig. 9b) the phosphate to be high during June-October, low during November-February and again rise slightly in February-April and then fall in April-May. According to the 5-year monthly mean for the coast as a whole (Fig. 9b), the major peak occurs in October and the minor one in March with the first fall in January and the second one in April.

The dissolved inorganic phosphates along the coast varied generally between 0.22-2.06 $\mu g\ at/l$ during the 5-year period of study, although values as high as 4.17

μg *at/l* in August 1962 at Karwar were encountered (Table II). The range is more at Karwar than the southern stations. The average minimum values for the 5 years at Karwar, Chendia, Ankola and Kumta were 0.25, 0.28, 0.30 and 0.30 μg *at/l* respectively. It equals at the last 2 places, whereas at Karwar and Chendia it is lower. The maximum values have an inclination to become lower towards the south and the respective average values at Karwar, Chendia, Ankola and Kumta were found to be 1.71, 1.15, 0.84 and 0.94 μg *at/l*. Complete depletion of this nutrient is not noticed along this coast.

The occurrence of the maximum values (Table II) and the major peaks (Fig. 6) coincides mostly. But the minimum values do not appear simultaneously with the respective months of fall in majority of the cases. However, they are restricted to the periods of falls and are distributed between the fall of November-February and April-June.

A comparative examination of the annual mean values (Fig. 10) and the study of the mean for the entire coast i.e. 0.44, 0.43, 0.46, 0.46 and 0.50 μg *at/l* during 1960, 1961, 1962, 1963 and 1964 respectively point out that the values in the second year registered a fall from the first and then went up in the next year and remained the same the year after. In the last year it again went up. Individually, Karwar appears to be slightly different from this (Fig. 10) in the fact that after 1962 it fell again in 1963. In 1964 it showed a slight increase. At Ankola, however, it showed a slight fall in 1964. The average value of the phosphate for the coast for the 5-year period was 0.46 μg *at/l*. The values at Karwar and Ankola were lower to this and at Chendia and Kumta higher (Fig. 10). In spite of the highest values, the value at Karwar was slightly lower, namely 0.45 μg *at/l* against the values 0.46, 0.45 and 0.48 μg *at/l* at Chendia, Ankola and Kumta respectively.

Nitrites : High concentrations of nitrites in the waters along the coast are recorded during May-August and again in November-December (Figs. 7 and 9b). The peaks during the latter period are generally of secondary importance except in 1963 when they were quite predominant. This peak at Ankola appeared a month earlier than the usual November-December period. The peaks in November at Kumta in 1960 and at Karwar in 1961 were also slightly higher than the respective preceding peaks in July and May. Sometimes as at Kumta in 1961 and 1962, a secondary peak does not appear and instead the values remain low during September 1961 to April 1962 and August 1962 to May 1963 respectively. Generally (Figs. 7 and 9b) the nitrites showed very low values during January-April and September-October (the primary peak occurring in between in May-August) and in many individual samples they were totally absent. The monthly mean values for the coast for the 5-year period (Fig. 9b) show the primary peak to occur in June and the secondary in December. The falls according to this are in October and February and appear to be more or less of the same calibre though the latter appears to be slightly lower.

The variations of nitrites during the 5 years of study was from 0.0 to 8.33 μg *at/l*. This high value was observed at Karwar once in June and again in September 1964 and it forms the highest for the coast for the entire period of study. The occurrence of the maximum value coincides mostly with the occurrence of peaks. The occurrence of the minimum values at the same time does not strictly adhere to any occasion and is distributed between the falls during January-April and September-October but mostly in the second time.

The maximum values at the different centres (Table II) as well as their mean, namely 4.49, 3.59, 2.61 and 1.78 *μg at/l* at Karwar, Chendia, Ankola and Kumta

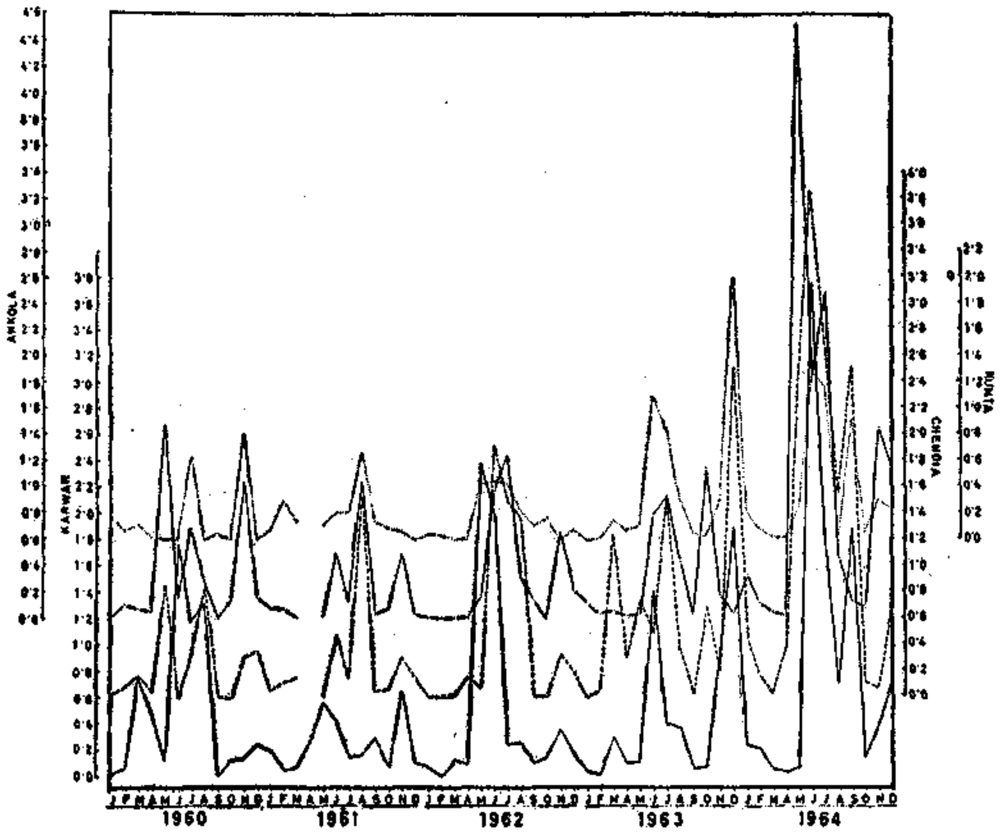

FIG. 7. Nitrites *μg at/l* (mean values).

respectively show this nutrient to have higher values in the north and to deplete succeedingly towards to southern stations. An year to year comparative scrutiny of these maximum values (Table II) and their mean for the coast, namely 1.94, 1.80, 2.59, 4.03 and 5.25 *μg at/l* for 1960, 1961, 1962, 1963 and 1964 respectively prove the last year to have very high values of nitrites.

The annual mean figures also (Fig. 10) show that the values in 1964 were high except at Kumta where a slightly lower value was noticed. The pattern of annual fluctuations appears to be more or less the same. The annual average values for the coast were 0.29, 0.23, 0.33, 0.47 and 0.29 *μg at/l* during 1960, 1961, 1962, 1963 and 1964 respectively. The 5-year mean values at Karwar, Chendia, Ankola and Kumta were respectively 0.49, 0.56, 0.47 and 0.26 *μg at/l*. The 5-year mean for the whole coast taken together was 0.44 *μg at/l* and the values at Karwar, Chendia and Ankola were more than this and at Kumta much less (Fig. 10). Though the maximum values were the highest at Karwar (Table II), the nitrite concentration in the sea-water was highest at Chendia. It was the lowest at Kumta where the maximum values were also found to be comparatively small.

Silicates : The silicate content attains a high peak generally during July-August and remains fairly high throughout the rainy season (Figs. 8 and 9b). In the last year (Fig. 8) the peaks occurred at Karwar in September and at Chendia in October. After the peak the values fall in September and continue to do so till December. During January-May (first part only), it reaches the lowest level. In the latter part of May when there shall be a few pre-monsoon showers along this coast an upward trend can be noticed and it becomes high at the height of the rainy season.

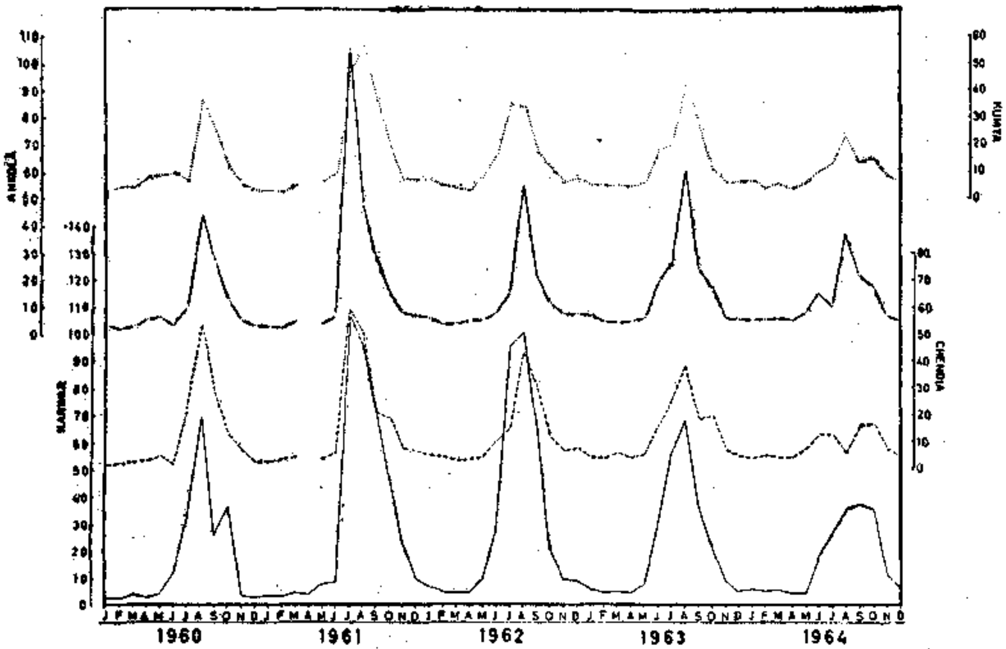

FIG. 8. Silicates *μg at/l* (mean values).

The variation of silicates during the troughs is little as it was observed to be roughly between 2.1 and 8.5 *μg at/l.* Still lower values were recorded during 1960 (Table II), and the lowest registered during the 5 years of study was 1.2 *μg at/l* at Kumta in the second half of January. The minimum values generally occurred during February-April.

The highest value for the entire 5-year period was 149.25 *μg at/l*, noticed at Karwar. The maximum values along the coast (Table II) generally appear first in the north and then in the south. For instance, in 1960, though the maximum appeared at all the places in August it occurred in the next year at Karwar, Chendia and Ankola in July and at Kumta in August. In 1962 and 1963, the maximum values occurred in July at Karwar and at the southern stations in August. In the last year, the values occurred in August at all places except Chendia where it was observed in October. The maximum values as can be seen from Table II tend generally to become smaller towards the southern centres. It was the highest at Karwar and lowest at Kumta.

The annual fluctuations of silicates (Fig. 10) exhibit the same pattern at Chendia, Ankola and Kumta. The values at these places rise and fall alternately in successive years. At Karwar, during the last 3 years, unlike other places, the silicate content kept diminishing. The annual mean values for the coast as a unit, viz. 12.31, 22.29,

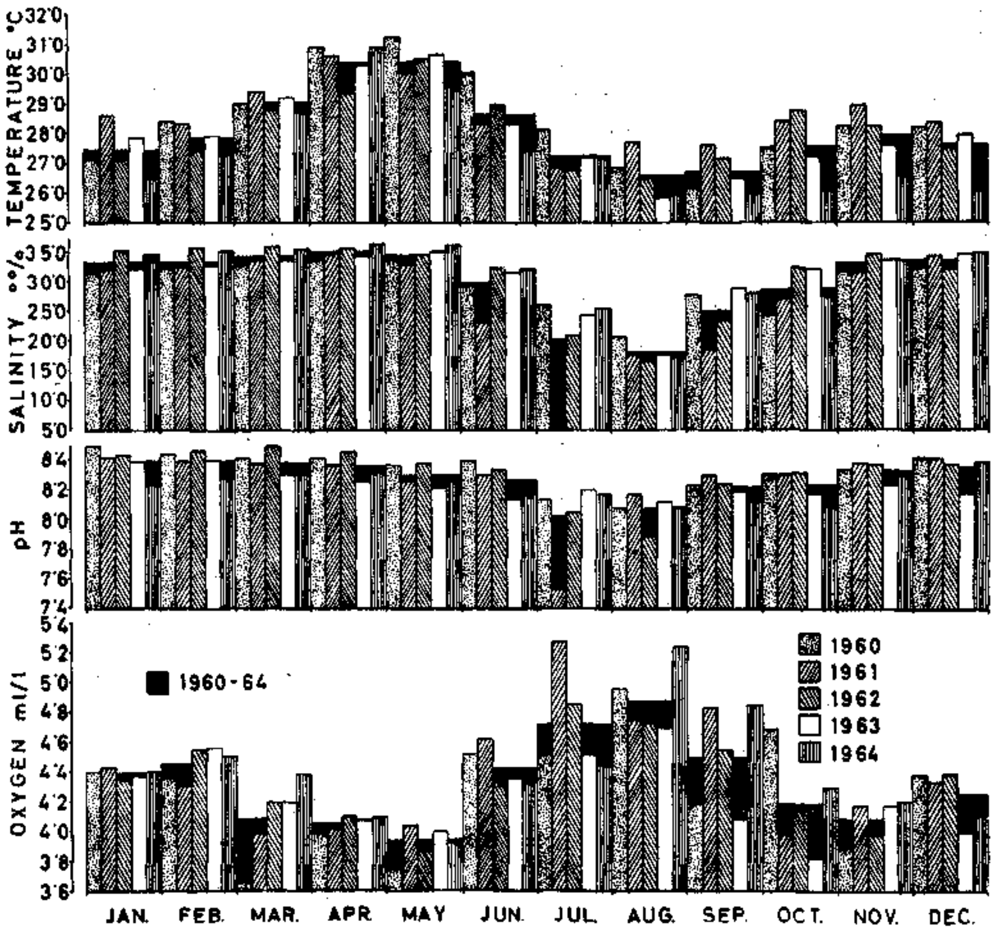

FIG. 9a. Monthly mean values for the coast as a unit.

17.12, 15.82 and 11.71 μg *at/l* for 1960, 1961, 1962, 1963 and 1964 respectively and their respective averages of maximum values for the coast 50.35, 97.07, 86.03, 68.22 and 39.40 μg *at/l* lend support to this. On the whole, the silicates were observed to be more along the coast in 1961 when the rainfall (Fig. 11) was unusually high. The 5-year averages of silicates at Karwar 23.29, Chendia 12.76, Ankola 14.51 and Kumta 12.86 μg *at/l* illustrate that they attain higher concentrations in the north than south, and the respective mean maximum values at these places, namely 106.52, 53.74, 66.32 and 46.28 μg *at/l* support this. Consequently the values at Karwar (Fig. 10) appear to be much higher than the average for the coast for 5 years which was 15.85 μg *at/l*. On the other hand, the values at Chendia, Ankola and Kumta appear to be lower than that for the coast as a whole. The annual mean values in 1960 and 1964 at Karwar and 1963 at Ankola approximate to the 5-year coastal mean. The values in 1961, 1962 and 1963 at Karwar exceed the coastal mean. The annual mean values in 1961 at all the 3 southern stations also exceed this, whereas during other years they are lower.

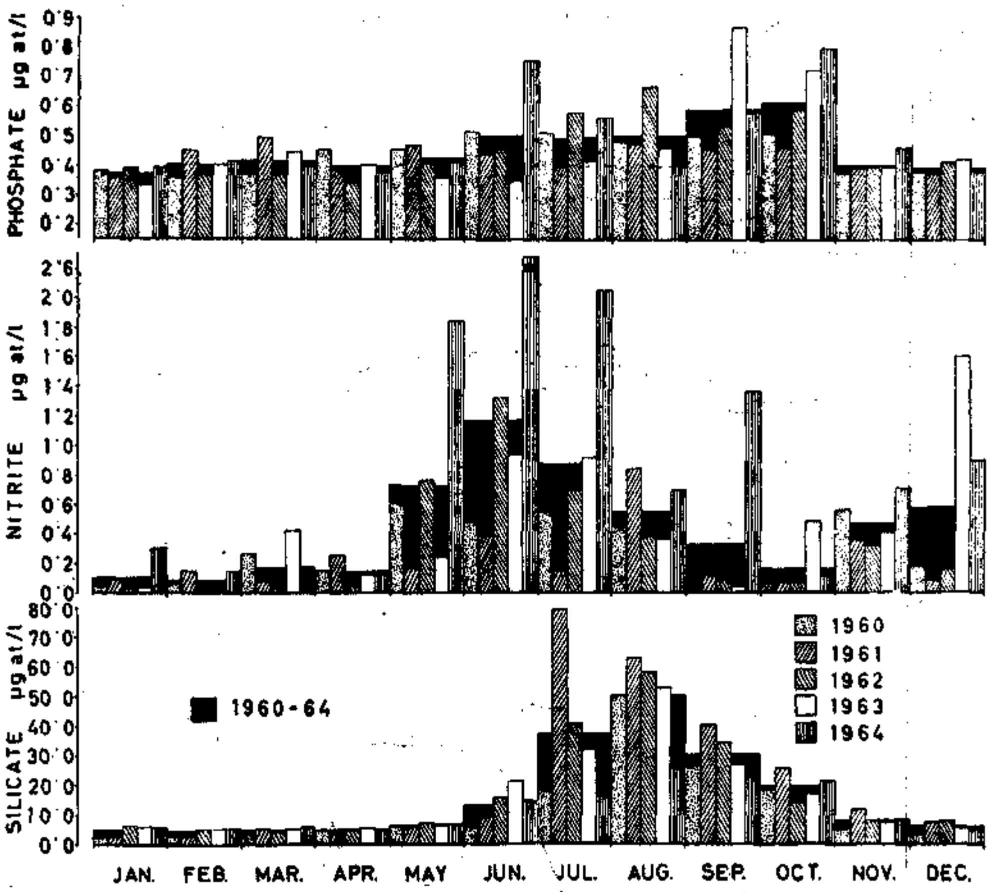

FIG. 9b. Monthly mean values for the coast as a unit.

DISCUSSION

As has been observed by Ramamurthy (1963), the surface temperature of the sea-water off the North Kanara Coast shows a definite double oscillation and it has been observed more or less common to our coastal waters by various workers (see Subrahmanyan 1959). The fall in temperature during July-September and December-February coincide with the south-west monsoon and winter season respectively. Of the two, the latter does not generally reach the low level of the former in the west coast, whereas in the east coast (Chacko *et al.* 1954, Ganapati and Murthy 1954, Ramamurthy 1953 and Prasad 1957) the primary fall occurs in January which marks the period of north-east monsoon and the cold climate and the secondary one during June-July corresponding to the south-west monsoon season.

The major falls of the sea surface temperature in the west and the east coasts claim the influence of monsoon on them. However, from the present observation

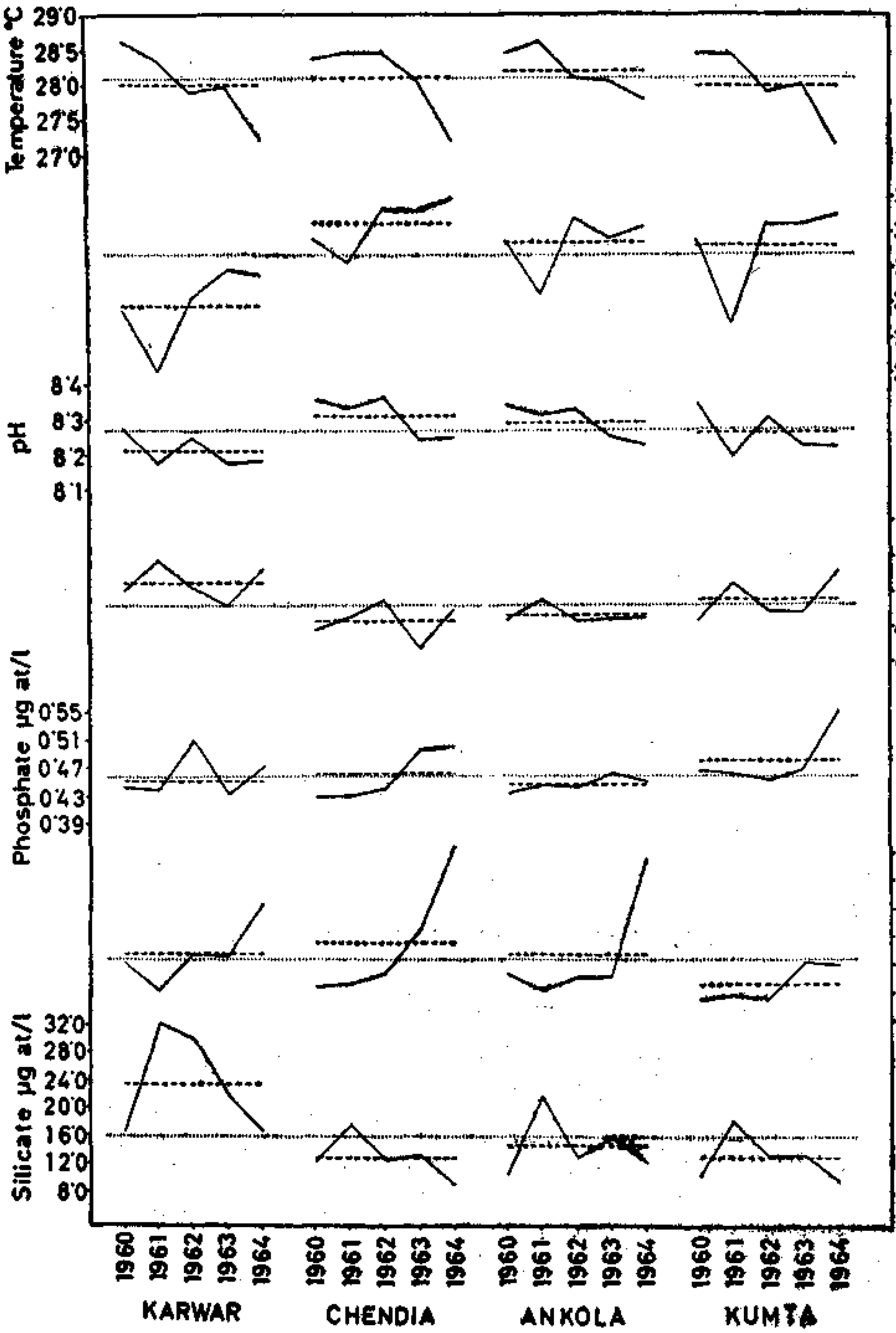

FIG. 10. Annual mean values (continuous line) and five-year mean values of each place (broken line) and of the coast as a unit (dotted line).

along this coast it does not appear wholly responsible (Noble, MS), for the lowest temperature values of the different years are not directly proportionate to the total rainfall (see Table II for the minimum temperature and Fig. 11 for the rainfall at

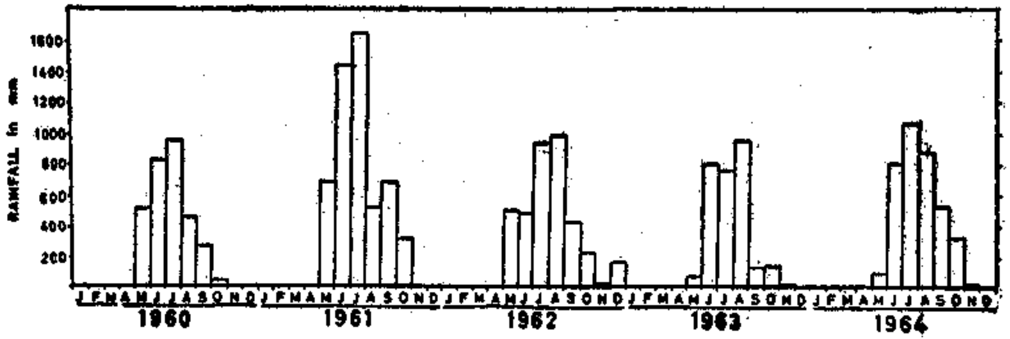

FIG. 11. Rainfall at Karwar.

Karwar). The minimum temperature at Karwar for example in 1961 when the rainfall was the highest was 26.2°C against 25.5 and 25.3°C of 1960 and 1962, 24.4 °C of 1963 and 24.0 °C of 1964 when there was only normal rainfall. Apart from this, the occurrence of the minimum temperature values and the peak of the monsoon do not seem to coincide. However, very heavy rain is observed invariably preceding the occurrence of the minimum temperature (Table VI). In the last year when the lowest temperature occurred, there was no rain at all. The occurrence of the minimum values at a date later to the heaviest rains also shows that the low values are caused by some factor other than the rainfall. Banse (1959) attributed the low surface temperature during the monsoon months in the south-west coast of India to upwelling. Ramamurthy (1963) also considers it an indicator of upwelling along this coast, but it is worthwhile to investigate on this further.

TABLE VI

Sequence of occurrence of heavy rains and the minimum temperature at Karwar.

Years	*Heavy rains*	*Minimum temperature*
1960	4th week of July	1st week of August
1961	4th week of June	1st week of July and 3rd week of August
1962	2nd week of August	3rd week of August
1963	1st week of July	2nd week of August
1964	2nd week of July	1st week of October

The occurrence of the minimum temperature in the monsoon period, as already mentioned earlier in the observations, first in the north and then in the south along this coast necessarily implies the movement of a column of cold water in the inshore area from north to south during the rainy season. As this water drifts to the south it gets gradually warmer with the consequence that at Kumta the minimum temperature is generally higher than that at Karwar.

The temperature along the North Kanara Coast attains the maximum in April-May. In the south-west (Chidambaram and Menon 1945, George 1953, and Subrahmanyan 1959) and the south-east (Chacko *et al.* 1954, and Prasad 1957) coasts it occurs in May. Bombay (Bal *et al.* 1946) has the highest temperature in June, and Madras (Ramamurthy 1953) and Visakhapatnam (Ganapati and Murthy 1954) in the Bay of Bengal in October.

The salinity is very high in summer (April-May) and low in the wet monsoon months (July-August). The fall in July-August is likely to be due to the influence of rain and drainage from the land and it is very low at Karwar on account of Kali River (Fig. 1) discharging directly into the Bay. The transition from this low values to the higher ones of the summer takes place gradually during the post-monsoon months. In certain years there appears another fall in salinity during December-January. This secondary fall when occurring is more emphasized in the south. As the north-east monsoon is not felt at Calicut, the secondary fall of December-January has been attributed to the effect of the coastal current bringing in Bay of Bengal water around the Peninsula and flowing on the west coast in a north-westerly direction (Subrahmanyan 1959). The effect of the north-east monsoon is totally absent along the North Kanara Coast also and hence the secondary fall during December-January is possibly due to this north-westerly coastal current. Further north, in Bombay, the secondary fall may be noticed in February (see Fig. 1 and Table I of the paper of Bal *et al.* 1946) even though the authors made no mention of it. A similar lowering of salinity appears along the east coast, first at Visakhapatnam in September-October (La Fond 1954, 1958a & b; Ganapati and Rao 1958, and Ganapati and Sharma 1958); then in Madras in October-December (Ramamurthy 1953, and Thirupad and Reddy 1959) and later in the Palk Bay and Gulf of Mannar during January-February (Jayaraman 1954) caused by a southerly current along the coast.

It can be presumed from the more steep secondary fall at Kumta in the south than at Karwar in the north along the North Kanara Coast, that the influence of the current fades as it flows north. The absence of the double oscillation during some years, particularly conspicuous at Karwar, is probably because the coastal current which brings in water of low salinity from the east coast does not come so far north in these years as to reach Karwar or if it does it is not possibly touching these inshore waters.

The maximum salinity value of 37.54‰ obtained along this coast during the 5-year period was at Chendia. At Karwar it was 36.82‰ only. While dealing with the mackerel fishery of Karwar, Pradhan (1956) reported very high salinity values during October-March of 1948-52 and the maximum values obtained during these months of 1960-64 comparatively are much low (Table VII). Palekar and Bal (1957) also have observed a value as high as 38.4‰ during January-May. Values as high as those recorded by Pradhan (1956) and Palekar and Bal (1957) have not been observed along this coast at any time during the 5 years of the present study and that of Ramamurthy (1963) during 1954-58. Bal *et al.* (1946) observed a value of 38.4‰ in May off Bombay coast and salinity as high as 40-41 ‰ are recorded in the Persian Gulf and Red Sea (Sverdrup *et al.* 1942); and the high values observed in Karwar Bay by Pradhan (1956) and Palekar and Bal (1957) where Kali River opens directly into it and especially in the post-monsoon winter months is probably errors in estimation.

TABLE VII

Maximum salinity values (in °/₀₀) at Karwar

Months	Periods	
—	1948-52	1960-64
October	37.8	33.75
November	38.0	35.10
December	38.7	35.20
January	38.4	35.21
February	40.8	35.85
March	37.9	35.96

A comparative study of the maximum records of the salinity along the east coast, namely 34.0‰ at Visakhapatnam (Ganapati and Murthy 1954), Madras 34.94‰ (Ramamurthy 1953), Mandapam area 37.45‰ (Prasad 1958) and west coast, namely 35.89‰ at Calicut (Subrahmanyan and Sarma 1960), North Kanara Coast 37.54‰ (present observation) and Bombay 38.40‰ (Bal *et al.* 1946) reveals a tendency in the maximum values to become higher towards the south in the east coast and towards the north in the west coast. Sea-water with high salinity values from the Red Sea is reported to enter the Arabian Sea (Panikkar and Jayaraman 1956) and this increase in values towards the north in the west coast is possibly due to the admixture of Red Sea water. Quite a good northern portion of the Bay of Bengal may be considered estuarine due to discharge of big rivers into it (Subrahmanyan 1960) and the increase in value towards the south in east coast can be due to the influence of the Indian Ocean.

As for temperature, the occurrence of minimum values for salinity and the rainfall also does not coincide, the former always succeeding the latter. The rainfall at the time when these minimum values appeared were comparatively much less. As has been mentioned in the case of temperature the local rainfall does not appear to be the only factor determining the occurrence of these minimum values also. It may be largely due to the fresh-water flowing down into the Bay from the river, and hence possibly depends on the amount of rainfall in the areas upstream.

Fluctuations of pH is unimodal, the fall occurring in July-August and the peak in January-February. Bal *et al.* (1946) observed the pH in Bombay waters to be high during April and low in December. According to Thirupad and Reddy (1959) the pH showed no marked fluctuations in Madras even though Ramamurthy (1953) observed high values during April-June and December and low during July and January. But Ramamurthy (1953) himself has suggested the need for more accurate studies with sensitive methods for reliable results. The above studies were only at single stations for short periods. On the other hand, the present study is for 5 years each for 4 different places along the coast.

The range in oxygen mean monthly values along the North Kanara Coast has been found to be between 3.01 and 5.59 ml/l. Ramamurthy (1963) found the range here to be between 2.75 and 5.31 ml/l.

At Madras, Jayaraman (1951), Ramamurthy (1953) and Thirupad and Reddy (1959) found the oxygen to be high during November-February and low during May-August. In Gulf of Mannar and Palk Bay (Jayaraman 1954) the seasonal fluctuations of dissolved oxygen show no marked variations in the various months. Oxygen was observed to be high during March-April and low during June at Waltair by Ganapati and Rao (1958). According to Kasturirangan (1957), the oxygen at Calicut is low in September and high in November. The period May-September showed no uniform character for the 4 years of study there. But Subrahmanyan (1959) observed at Calicut that after the low values in March, oxygen increases in April-June. A decline in July-August follows this. Again it is observed to increase in September and reach high values in November. The dissolved oxygen along the North Kanara Coast, however, has been observed to be bimodal, the peaks occurring during December-February and June-September and the falls during March-May and September-November.

The dissolved inorganic phosphate in temperate waters has been generally observed to have a bimodal seasonal distribution, having a major winter and a minor summer maximum. Along the North Kanara Coast too a double oscillation has been observed, the values being high during February-April and June-October and low during April-June and November-February. Similar double oscillations were observed by George (1953) and Rao and George (1957) at Calicut and by Ganapati and Rao (1958) at Waltair. Subrahmanyan (1959) at Calicut, Jayaraman (1951), Thirupad and Reddy (1959) and Subrahmanyan and Sen Gupta (1965) at Madras found only a unimodal curve. Subsequent to the minimum in November, according to Subrahmanyan and Sen Gupta (1965), the values keep oscillating till the next peak in June. But Ramamurthy (1953) at Madras, Jayaraman (1954) and Chacko *et al.* (1954) at Gulf of Mannar, Palk Bay and Kundugal Gut and Bal *et al.* (1946) in Bombay could find no marked seasonal cycle.

Subrahmanyan (1959) tabulated the range in phosphate values of various places in the world and he observed the phosphate at surface at Calicut to vary between 0.13 and 1.68 μg *at/l* and suggested the high fertility of our coastal waters. Rao (1957), however, found a still higher value ranging from 0.33 to 1.92 μg *at/l* there. Though the monthly mean values varied between 0.25 and 1.35 μg *at/l*, the North Kanara Coast had a wider range, normally from 0.22 to 2.06 μg *at/l* (individual values). As has already been mentioned earlier in this paper, value as high as 4.17 μg *at/l* has also been recorded here. Along Indian coasts Jayaraman (1951) has reported 3.0 μg *at/l* once from Madras. Sverdrup *et al.* (1942) report 3.5 μg *at/l* from the Pacific Ocean. The data indicate that phosphate values vary over a wider range and the magnitude of the variation differs from year to year.

The study of nitrites in our waters is too limited (Bal *et al.* 1946, Jayaraman 1951, Ramamurthy 1953, Thirupad and Reddy 1959 and Subrahmanyan and Sen Gupta 1965). In the North Kanara Coast a definite double oscillation in its seasonal distribution with the major and minor peaks in May-August and November-December respectively has been observed. A bimodal distribution with high concentrations at corresponding periods has been observed at Madras by Thirupad and Reddy (1959), and they observed it to range between 0.0 and 0.55 μg *at/l*. Jayaraman (1951) also gives the same variation during his studies there. But at Karwar it has been observed to be between 0.0 and 8.33 μg *at/l* and at Bombay Bal *et al.* (1946) recorded it to be from 0.32844 to 11.93094 μg *at/l* (4.60 to 167.1 mg./m^3). These values are sufficient enough to substantiate the high fertility of the west coast of India over the east coast.

The silicates in the North Kanara Coast is unimodal in its seasonal fluctuation, the peak being in July-August during the south-west monsoon period. At Calicut (Subrahmanyan 1959) also the silicate was maximum during the south-west monsoon (July to September), whereas in Bombay Bal *et al.* (1946) observed it to peak during January-March when there is practically no rainfall at all. High concentrations of silicates along the east coast, however, were observed in October-January during the north-east monsoon period (Ganapati and Rao 1958, Jayaraman 1951 and 1954, Ramamurthy 1953, Thirupad and Reddy 1959 and Chacko *et al.* 1954).

It has been observed along the North Kanara Coast itself that the maximum values of silicates appear in succession from north to south and that these values diminish towards the south. The successive occurrence of the peak period can possibly be feasible along the west coast as a whole as it occurs a little later at Calicut in the south (Subrahmanyan 1959). Dealing with the occurrence of lowest temperatures along the North Kanara Coast it was mentioned that a cold water column moves in a southerly direction parallel to the coast. The successive occurrence of high silicates indicate that this water column is rich in this nutrient salt. Successive occurrence of high silicates together with low salinity values in a north to south direction during July-December by a southerly current was suggested for the east coast by Ganapati and Rao (1958).

The range in silicates at the various places has been given by Subrahmanyan (1959), and our values compared to records of other seas are considerably high. At Karwar the maximum value was observed to be 149.25 *μg at/l* and this appears to be due to the influence of fresh-water from Kali River. High values were observed in the inshore areas where such fresh-water influence is found, as for instance, at Calicut where the Korapuzha opens into the sea Rao and George (1957) obtained values up to 260.0 *μg at/l* and the minimum value recorded by them there was also high, 20.0 *μg at/l*. At Calicut, Subrahmanyan (1959) claims that the silicate contents never go below 5.0 *μg at/l*. Along the North Kanara Coast, the silicate content, on the other hand, fell as low as 1.2 *μg at/l*. Still lower values namely 0.7417 *μg at/l* which appears to be our lowest, is recorded from Kundugal Gut in Gulf of Mannar by Chacko *et al.* (1954).

Interrelationships of the various hydrological factors are shown in Fig. 12. The relation between the temperature and salinity is parallel, the occurrence of their peaks and falls being contemporary. Changes in temperature may be result of interaction of many factors such as upwelling, effect of the atmospheric temperature, rainfall and wind force. The fall in salinity during the rainy season can be attributed to the rainfall which as seen in the figure has a distinct and indirect correlation to it. The relation between pH and salinity (Fig. 12) is also parallel and like salinity its relation to rainfall is inverse.

The relations between pH and dissolved oxygen in the sea-water has been observed to be direct, the maximum of pH coinciding with the maximum of dissolved oxygen and *vice versa*. But Riley and Skirrow (1965) are of opinion that variations of these are produced by localized concentrations of pH-influencing-substances. Brackish water, estuarine, tidal and harbour waters and muds and areas of local industrial contamination may show considerable deviations from the pH ranges expected in the open ocean. The relation between the pH and oxygen along the North Kanara Coast is direct except during the rainy season when it becomes deeply inverse (Fig. 12). Ramamurthy (1963) feels that the greater decrease in pH at Karwar during rainy season may be due to the influence of the flood waters of Kali

River. However, it is interesting to note that even at the southern stations where there is no immediate influence of river influx the pH shows the same trend and hence the phenomenon is to be considered peculiar to this coast and that it is effected by

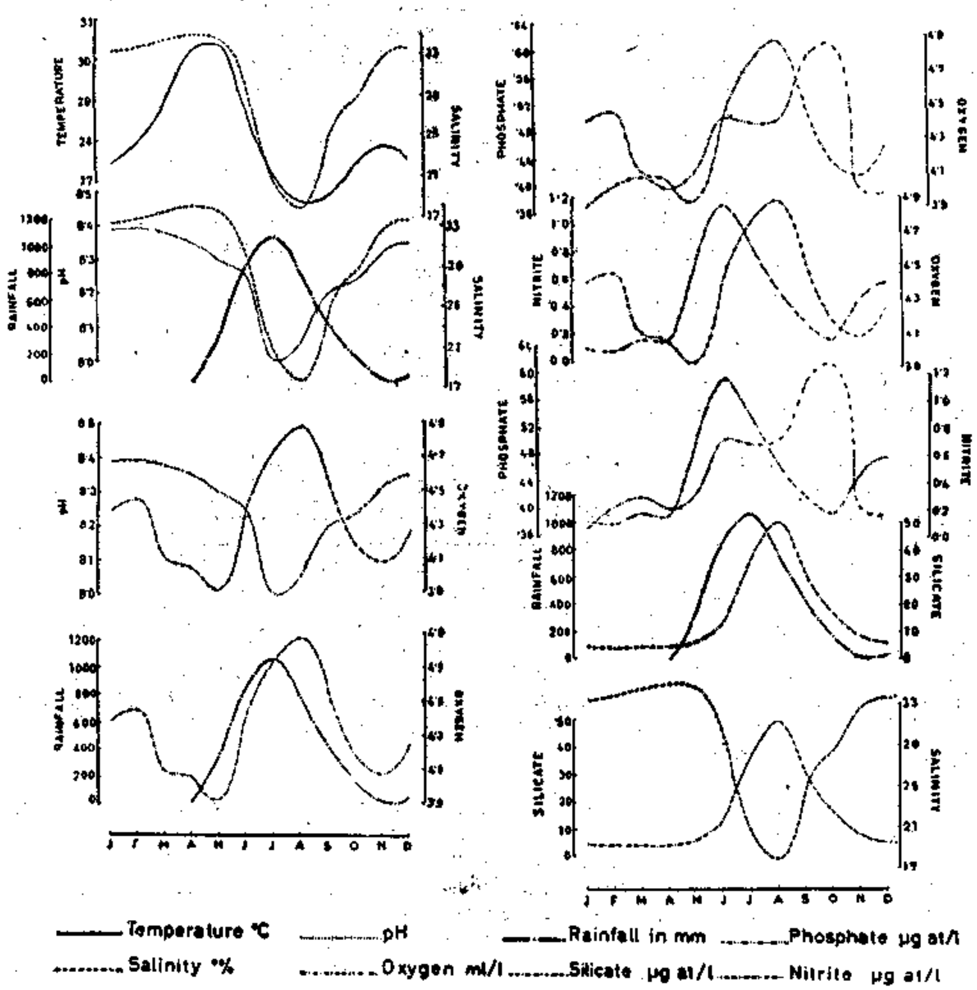

FIG. 12. Interrelations of the various factors. The values are the monthly averages for the five-year period for the North Kanara coast as a unit.

drainage from land. The relation between pH and rainfall as has been mentioned is inverse, whereas with regard to dissolved oxygen in the sea-water it has been observed to be direct.

The nutrient salts are abundant during June-October. The nitrites attain the peak just before heavy rains (in June) and the phosphates just afterwards (in October). Peaks of silicates occur during heavy rains in August. The relation between silicates and rainfall is strictly parallel, with the difference that (Fig. 12) heavy rains occur much ahead of the occurrence of the peak of silicates. As the peaks of nutrients do not occur contemporarily to the peak of rainfall, it is reasonable to think that these peaks are not caused by the rainfall though it seems to affect it. River water is observed to contain very high concentrations of silica (Rao and George 1959 and Ramamurthy 1963). Influx of river water and drainage from land appear to contribute largely to the rise in silicates in the sea-water in the inshore area during the south-west monsoon season.

The silicates show an inverse relation to salinity (Fig. 12). A similar relation between the two was noticed here by Ramamurthy (1963). It has been observed in the Bay of Bengal by Jayaraman (1951 and 1954) and Ganapati and Rao (1958). The inverse relation between silicates and salinity does not seem to be interdependent and influencing each other but just a coincidence of the rainy season.

The relations between oxygen and phosphates, and oxygen and nitrites are interesting. The phosphates and nitrites are less when oxygen is more and when they become more oxygen becomes less. Oxygen in sea-water increases when there is increased photosynthetic activity and the nutrient salts in the water are then reduced due to utilization by plants. Through decomposition the nutrients increase afterwards and the oxygen begins to fall. Hence when the nutrients are more, oxygen becomes less. The fall of oxygen continues further when it is used up in the oxidation of nutrients which are abundant in the water. Consequently there occurs a depletion in the nutrients also. Though the relation between phosphates and oxygen is clear as explained above, it is not so well marked with nitrites especially during rainy season.

Summary

Studies on temperature, salinity, pH, dissolved oxygen and nutrients like inorganic phosphates, nitrites and silicates of the sea-water off the North Kanara Coast during 1960-64 are presented.

The temperature, oxygen, phosphates and nitrites have been observed to be bimodal in their seasonal distribution with primary and secondary peaks and excepting oxygen with primary and secondary falls. In the case of oxygen it is not safe to designate one fall as primary and the other as secondary. Salinity appears to be unimodal, but in some years bimodal. The pH and silicates are unimodal in their distribution.

The temperature and salinity are high in summer and low during monsoon and again rise and fall (not always in salinity) during post-monsoon months and winter respectively. The fluctuation in oxygen is just the opposite. pH is high in winter and low during monsoon. Nutrients are high in the south-west monsoon period. Phosphates and nitrites in them become low in post-monsoon season but show another peak and fall in the winter and summer respectively. Silicates, however, keep falling till they reach the low level during summer.

Fluctuations in some instances are interdependent and influencing each other but in others just a coincidence. Rainfall, river influx and drainage from land greatly influence the coastal waters. The sea-water off the North Kanara Coast has been observed to be rich in nutrient salts. A southerly drift of a coastal cold water mass has been detected during the rainy season and a northerly current has been observed in winter.

ACKNOWLEDGEMENT

The author is grateful to Dr. R. Raghu Prasad, Deputy Animal Husbandry Commissioner (Fisheries), Indian Council of Agricultural Research, New Delhi, for making corrections in the manuscript.

REFERENCES

BAL, D. V. *et al.* 1946. A preliminary record of some of the chemical and physical conditions in waters of the Bombay Harbour during 1944-45. *Proc. Indian Acad. Sci.*, **24B** : 60-73.

BANSE, K. 1959. On upwelling and bottom-trawling off the south-west coast of India. *J. Mar. biol. Ass. India*, 1(1) : 33-49.

CHACKO, P. I. *et al.* 1954. Meteorology and oceanography of the Kundugal Gut in the Gulf of Mannar. *Contributions from the Marine Fisheries Biological Station, Krusadi Island, Gulf of Mannar, No.* **1** : 1-20.

CHIDAMBARAM, K. AND MENON, M. D. 1945. The correlation of the West Coast (Malabar and the South Kanara) fisheries with plankton and certain oceanographical factors. *Proc. Indian Acad. Sci.*, **22B** : 355-67.

GANAPATI, P. N. AND MURTHY, V. S. R. 1954. Salinity and temperature variations of the surface waters off the Visakhapatnam Coast. *Mem. Oceanogr. Andhra Univ.*, **1**, Series 49 : 125-42.

———— AND RAO, D. V. S. 1958. Quantitative study of plankton off Lawson's Bay, Waltair. *Proc. Indian Acad. Sci.*, **58B** : 189-209.

———— AND SHARMA, V. D. 1958. Hydrography in relation to the production of plankton off Waltair Coast. *Mem. Oceanogr. Andhra Univ.*, **62**(2) : 168-92.

GEORGE, P. C. 1953. The marine plankton of the coastal waters of Calicut with observations on the hydrological conditions. *J. zool. Soc. India*, **5** : 76-107.

JAYARAMAN, R. 1951. Observations on the chemistry of the waters of the Bay of Bengal off Madras City during 1948-49. *Proc. Indian Acad. Sci.*, **33B** : 90-99.

————. 1954. Seasonal variations in salinity, dissolved oxygen and nutrient salts in the inshore waters of the Gulf of Mannar and Palk Bay near Mandapam (S. India). *Indian J. Fish.*, **1** : 345-64.

KASTURIRANGAN, L. R. 1957. A study of the seasonal changes in the dissolved oxygen of the surface waters of the sea on the Malabar Coast. *Ibid.*, **4**(1) : 134-49.

LA FOND, E. C. 1954. On upwelling and sinking off the East Coast of India. *Mem. Oceanogr. Andhra Univ.*, **49**(1) : 117-21.

————. 1958a. On the circulation of surface layers of the East Coast of India. *Ibid.*, **2** : 1-11.

————. 1958b. Seasonal cycle of the sea surface temperatures and salinities along the East Coast of India. *Ibid.*, **2** : 12-21.

NOBLE, A. Surface temperature and its relation to the duration of mackerel fishery at Karwar. (MS. Unpublished).

PALEKAR, V. C. AND BAL, D. V. 1957. Destruction of timber by marine organisms in the Karwar Port. *J. Bombay nat. Hist. Soc.*, **54**(4) : 962-64

PANIKKAR, N. K. AND JAYARAMAN, R. 1956. Some aspects of productivity in relation to fisheries of Indian neritic waters. *Proc. 8th Pacific Sci. Congr.*, **111A** : 1111-1122.

PRADHAN, L. B. 1956. Mackerel fishery of Karwar. *Indian J. Fish.*, **3**(1) : 141-85.

PRASAD, R. R. 1957. Seasonal variations in the surface temperature of sea water at Mandapam from January 1950 to December 1954. *Ibid.*, **4**(1) : 20-31.

———. 1958. Plankton calenders of the inshore waters at Mandapam, with a note on the productivity of the area. *Ibid.*, **5**(1) : 170-88.

RAMAMURTHY, S. 1953. Seasonal changes in the hydrogen-ion-concentrations and dissolved oxygen content of the surface waters of the Madras Coast. *J. Madras Univ.*, **23B** (10) : 52-60.

———. 1953. Hydrobiological studies in the Madras coastal waters. *Ibid.*, **23B** : 148-63.

———. 1963. Studies on the hydrological factors in the North Kanara Coastal waters. *Indian J. Fish.*, **10A**(1) : 75-93.

RAO, S. V. S. 1957. Preliminary observations on the total phosphorus content of the inshore waters of Malabar Coast off Calicut. *Proc. Indian Acad. Sci.*, **45B** : 77-85.

——— AND GEORGE, P. C. 1959. Hydrology of the Korapuzha Estuary, Malabar, Kerala State. *J. Mar. biol. Ass. India*, **1**(2) : 212-23.

RILEY, J. P. AND SKIRROW, G. 1965. *Chemical Oceanography*. Vol. I. Academic Press. London and New York.

ROBINSON, R. J. AND THOMPSON, T. G. 1948a. Determination of phosphates in sea water. *J. Mar. Res.*, **7**: 33-41.

———. 1948b. Determination of nitrites in sea water. *Ibid.*, **7** : 42-48.

———. 1948c. Determination of silicates in sea water. *Ibid.*, **7** : 49-55.

SUBRAHMANYAN, R. 1959. Studies on the plankton of the West Coast of India, Part II. Physical and chemical factors influencing the production of phytoplankton, with remarks on the cycle of nutrients and on the relationship of the phosphate content to fish landings. *Proc. Indian Acad. Sci.*, **50B** (4) : 189-252.

———. 1960. Observations on the effect of the monsoons in the production of phytoplankton. *J. Indian bot. Soc.*, **39**(1) : 78-89.

——— AND SARMA, A. H. V. 1960. Studies on the phytoplankton of the West Coast of India, Part III. Seasonal variations of phytoplankters and environmental factors. *Indian J. Fish.* **7**(2) : 307-36.

——— AND SEN GUPTA, R. 1965. Studies on the plankton of the East Coast of India, Part II. Seasonal cycle of plankton and factors affecting marine plankton production with special reference to iron content of water. *Proc. Indian Acad. Sci.*, **59B**(1) : 12-24.

SVERDRUP, H. U. *et al.* 1942. *The Oceans, their Physics, Chemistry and General Biology*. Prentice-Hall Inc., New York.

THIRUPAD, P. U. V. AND REDDY, C. V. G. 1959. Seasonal variations of the hydrological factors of the Madras Coastal waters. *Indian J. Fish.*, **6**(2) : 298-305.