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STUDIES ON THE PLANKTON OF THE NORTH KANARA COAST IN RELATION TO THE PELAGIC FISHERY*

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INTRODUCTION

THE role of plankton in the economy of the seas needs no emphasis. The North Kanara coast supports a rich fishery for mackerel which is a plankton feeder. However, there is no account of plankton of this stretch of the west coast of India.

The physico-chemical characteristics of the coastal waters of this region and the meteorological factors have been dealt with in detail by the author (1963) in a separate account. The present study relates to the seasonal fluctuations in the standing crop of plankton as well as those of the main groups constituting the phyto- and zooplankton, the phyto-zooplankton relationship and the relation of the plankton to the hydrological factors. Certain observations on the feeding habits of mackerel and oil sardines and the relation of the fishery to plankton and hydrological conditions are also included in this account.

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MATERIAL AND METHOD

Sampling stations were located approximately at a distance of 2 miles from the shore off Karwar, Chendia, Ankola and Kumta, covering a stretch of 40 miles of the coast. The depth of the sea at those places varied from 8-14 m. A total of 340 plankton samples (195 from Karwar collected during January 1954-December 1957, 48 from Chendia collected during June 1956-May 1958, 50 from Ankola and 47 from Kumta collected during January 1956-December 1957) formed the basis of the study. The collections were made by 15 minutes' horizontal surface hauls between 0600 and 0700 hrs. using a halfmetre net of organdie cloth having 36 strands/cm., towed from an out-rigger canoe.

After fixing the plankton in 5% formalin, the net-plankton volume was determined by displacement method (Sheard, 1947). The sample was then made up to a known volume (250 ml.) and from this an aliquot (1 ml.) was taken on a counting slide for examination of the different plankters. The genera, and in the case of the

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more common forms their species, were noted and the numbers expressed as per ml. of the standardised sample. The diatoms were counted as individual cells.

The analysis of the stomach contents of 780 mackerel (12.0 to 26.0 cm. in total length) collected from the shore-seine and gill-net catches and 108 oil-sardines (9.0-15.0 cm. in total length) collected from the shore-seine and cast-net catches during 1955-57 was made by the enumeration and points method (Hynes, 1950).

PLANKTON

The more common forms of phytoplankton and zooplankton and their occurrence in the North Kanara coastal waters are given in Tables I and III. Since no information is available on the plankton and its composition in this part of the west coast of India, it is felt that the Tables will give at least a general picture on these aspects.

TABLE I

Phytoplankton organisms occurring in the North Kanara coast and the period of their abundance during 1954-57

CYANOPHYCEAE :	
Trichodesmium erythraeum Ehr. ex. Gomont	.. December-March
Trichodesmium thiebautii Gomont	.. "
BACILLARIOPHYCEAE :	
Fragilaria oceanica Cleve	.. July-September
Thalassionema nitzschoides Grun	.. "
Thalassiothrix longissima Cleve & Grun	.. "
Thalassiothrix frauenfeldii Grun	.. "
Asterionella japonica Cleve	.. March-May & Sept.-Oct.
Pleurosigma spp.	.. January-April
Nitzschia closterium W. Smith	.. March-May & Aug.-Sept.
Nitzschia seriata Cleve	.. " "
Stephanophyxis sp.	.. January-March
Sceletonema costatum (Greville) Cleve	.. April-June
Thalassiosira spp.	.. January-June
Coscinodiscus spp.	.. August-December
Planktoniella sol (Wallich) Schutt	.. September-October
Lauderia annulata Cleve	.. January-March & July-August.
Schroederella delicatula (Peragallo) Pavillard	.. March-April
Leptocylindricus spp.	.. February-May
Guinardia sp.	.. "
Rhizosolenia spp.	.. September-February
Bacteriastrum spp.	.. August-May
Chaetoceros spp.	.. March-May & August-September
Streptotheca indica Karsten	.. June
Bellarochea malleus (Brightwell) Van Heurck	.. March-May
Ditylum sp.	.. February-March
Biddulphia spp.	.. January-February
Ceratulina bergonii Peragallo	.. December-January
Hemiaulus sp.	.. February-June
Hemidiscus herdmannianus (Greville) Mann	.. March-July
DINOPHYCEAE :	
Prorocentrum sp.	.. October-November
Peridinium spp.	.. October-March
Dinophysis miles Cleve	.. November-January
Dinophysis homunculus Stein	.. September-November
Ornithocercas sp.	.. November-January
Ceratium massiliense Gourret	.. August-October
Ceratium furca Ehr.	.. September-May
Ceratium trichoceros Kofoid	.. August-October
Ceratium fusus Ehr.	.. October-December
Ceratium tripos O. F. Muller	.. August-October
Ceratium dens	.. January-March

NET-PLANKTON VOLUME

The fluctuations in the mean monthly standing crop of plankton at the different laces are presented in Fig. 1. The volume of the net-plankton remained low during ecember-June when the bulk of the plankton was composed mainly of zoo-

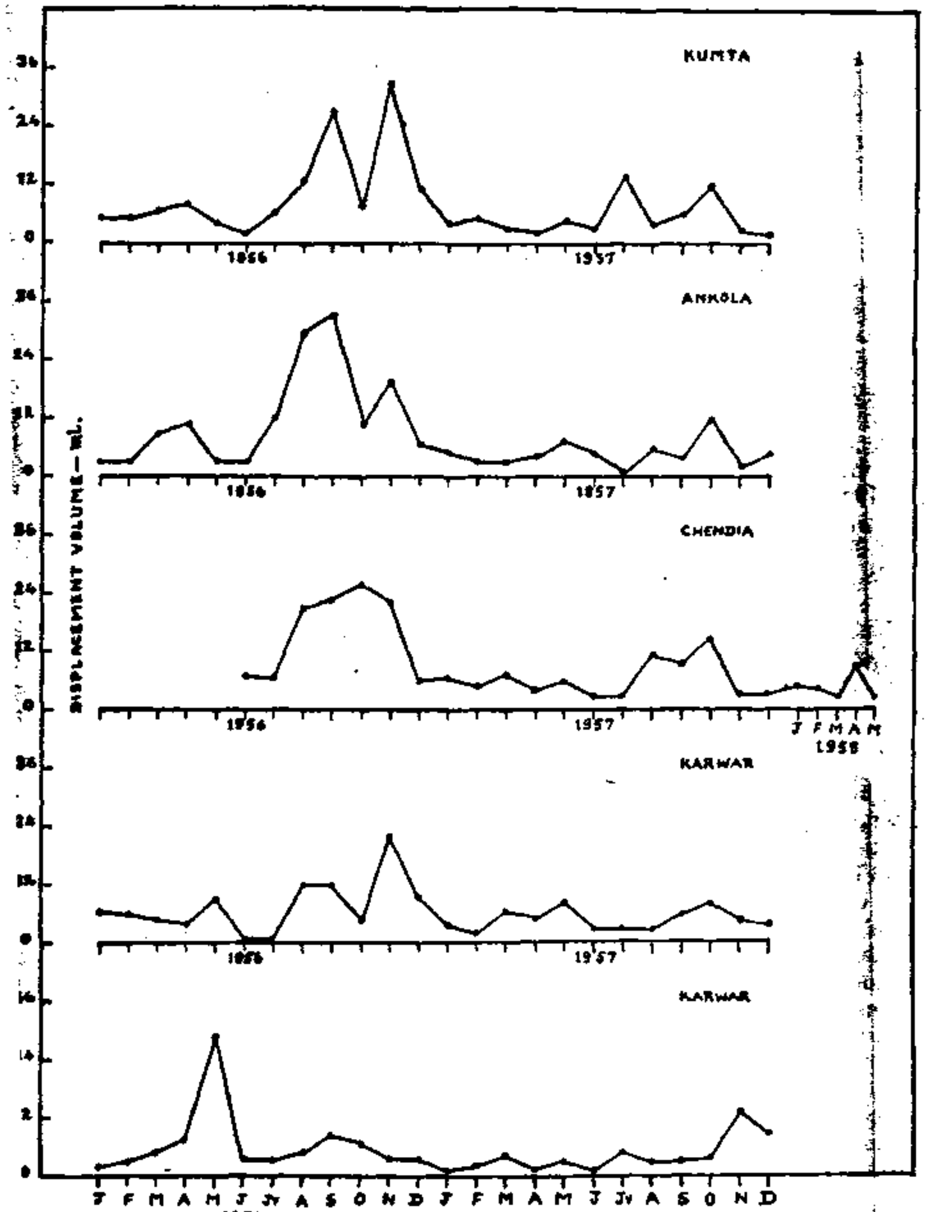

FIG. 1. Seasonal variations in the displacement volume of plankton in the surface waters of North Kanara coast.

plankton. The plankton volume in May 1954 at Karwar was, however, high due to a sudden swarming of *Noctiluca miliaris*. The standing crop of plankton generally registered a steep rise at all the sampling stations due to diatom blooms in July-August of the south-west monsoon season. At Karwar, however, the standing crop of plankton was poor compared to that of the other places which was due to the greater dilution of the coastal waters at Karwar consequent of the river discharge during the south-west monsoon period. The lowest monthly average salinity noticed at Karwar was 3.08‰* as against 15.24‰ observed at other centres. The plankton volume generally reached the peak during September-November. At this time the diatoms decreased in numbers whereas the dinoflagellates and zooplankton elements became abundant.

PHYTOPLANKTON

Bacillariophyceae : The diatoms formed the most important constituent of the phytoplankton of the North Kanara coastal waters throughout the year and they showed a distinct seasonal fluctuation (Fig. 2). *Fragilaria oceanica* and *Chaetoceros* spp. were the most prominent diatoms in the plankton. The former was present in the plankton only during the south-west monsoon season (May-September) and reached a peak (primary peak) in July-August. *Chaetoceros* spp. occurred throughout the year and the diatom maximum (secondary peak) noticed during March-May was constituted by these diatoms. However, the *Chaetoceros* maximum noticed in May 1957 at Karwar, represented the primary peak. It is of interest to note that the *Fragilaria* maximum was noticed when the salinity and temperature were low (13.15-25.10‰ and 24.5-27.4°C. respectively) and when westerly winds (N N W or W S W) of high velocity (1.3-5.2 knot-hr.) prevailed.

The monsoon diatom concentration at Karwar was less than at the other centres. Fig. 3 shows the fluctuations of diatoms in relation to salinity during June-September at the various sampling centres. The diatom concentration at Karwar, unlike at other centres, showed wide and frequent fluctuations corresponding to similar changes in the salinity conditions due to river flow.

The intensity of the diatom growth was less in 1957 than in 1956 in practically the whole of this coastal region. A study of the hydrological and meteorological conditions during May-September, the peak period for the diatoms in these two years (Table II) shows that this period in 1957 was marked by a significantly lower silica content and a higher salinity than the corresponding period of 1956 due to lower rainfall in the former period. The fact that the temperature of the water remained steadily higher in 1957 would also appear to be a contributory factor. Yet another factor which might have influenced the relative abundance of the diatoms in the monsoon season of 1956 and 1957 is the turbulence caused by wind action which was distinctly higher in 1957.

Comparing the diatom plankton of this coast with that of the other areas of the west coast observed by Subrahmanyan (1959), a more or less close similarity is revealed in the seasonal composition and variations. The findings of the present study also support the presence of a distinct seasonal cycle in the standing crop of

* Method described by Ellis, *et al.* in determination of water quality, Rept. No. 9 of U.S. Fish & Wildlife Service, 1946, was followed for estimation when low salinities were observed.

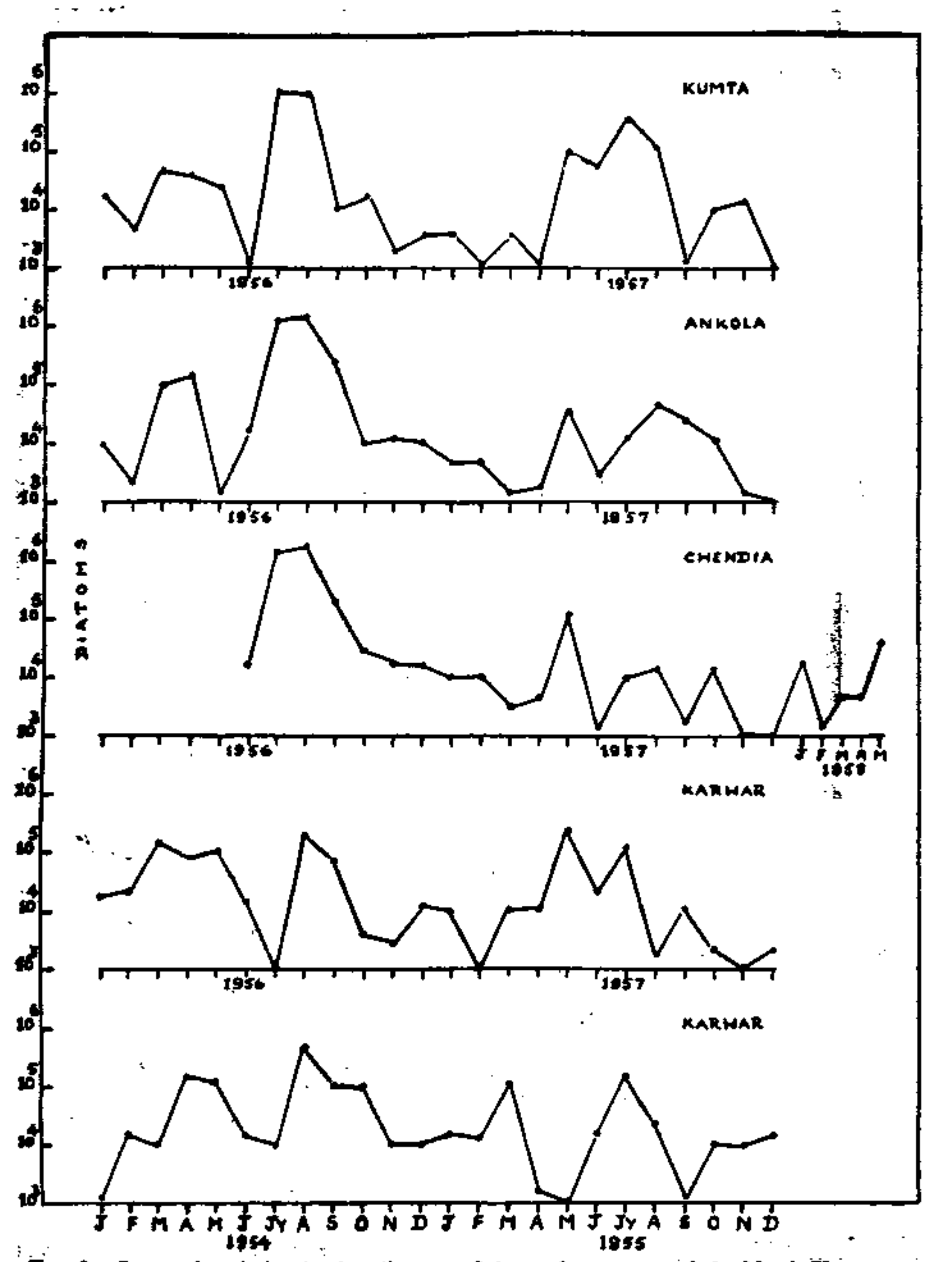

FIG. 2. Seasonal variation in the diatoms of the surface waters of the North Kanara coast ogarithmic scale.

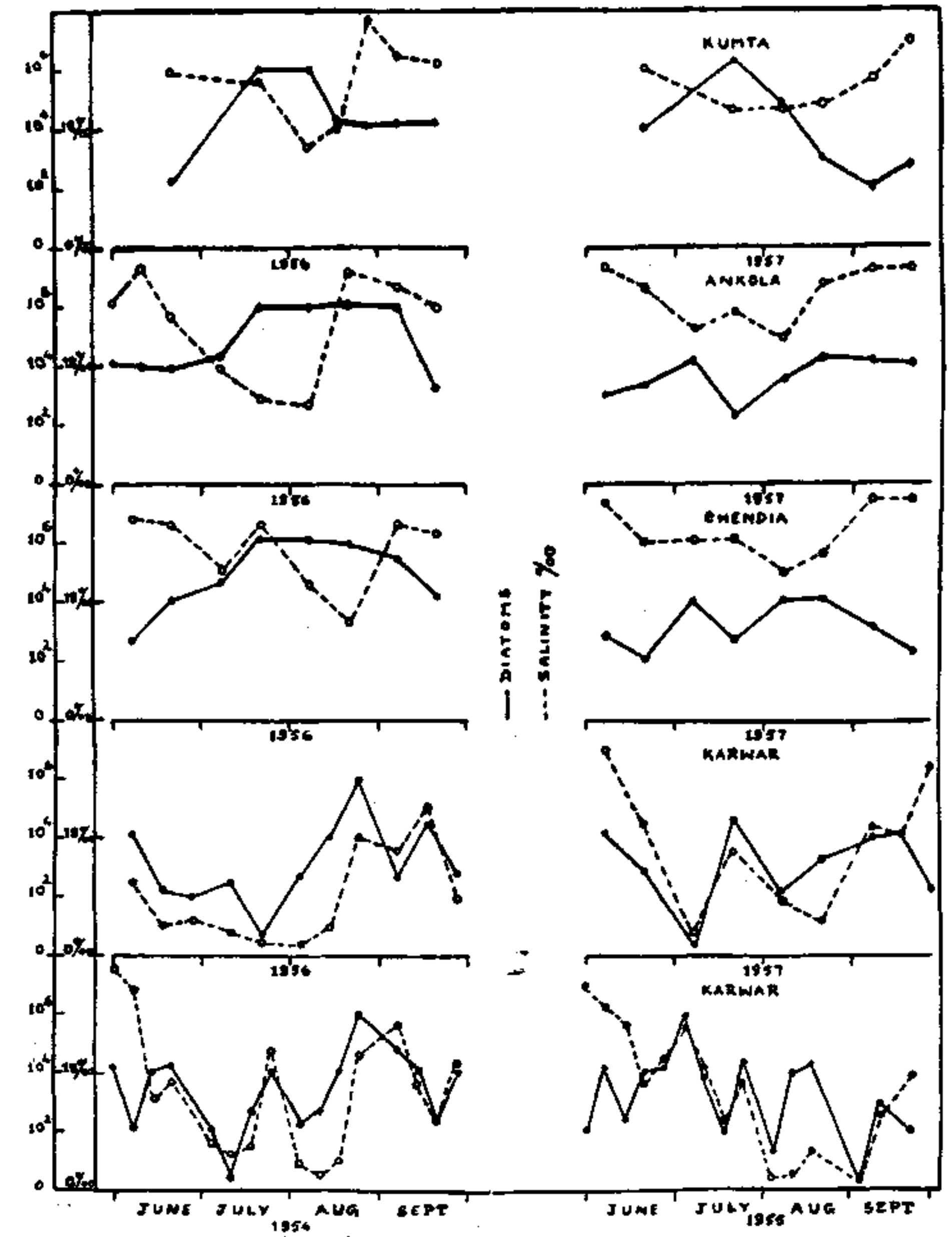

FIG. 3. Seasonal variations of diatoms in logarithmic scale and salinity in the surface waters of the North Kanara coast during June-September.

TABLE II

Surface temperature, salinity, silica, rainfall and wind velocity for the months May-September in 1956 and 1957

Place	Year	Temperature in° C.	Salinity in ‰.	Silica in µg. at.xL.	Total rainfall in cm.	Wind velocity in knots hr.
Karwar	1956	24.5–29.8	1.20–34.61	2.5–125.0	313.4	1.4– 4.8
	1957	25.0–31.0	3.40–33.5	3.0– 66.7	257.0	4.3–10.8
Chendia	1956*	23.0–28.5	15.39–30.98	2.0–56.7		
	1957	25.5–31.0	22.36–33.95	2.2–28.6		
Ankola	1956	25.0–28.6	12.28–34.03	3.2– 48.8		
	1957	26.0–32.4	21.88–34.34	2.3– 28.6		
Kumta	1956	24.5–29.2	11.89–34.82	2.6– 83.3		
	1957	25.0–31.6	20.53–33.95	2.5– 18.5		

* Figures given are from the data available from June-September 1956.

diatoms reported from other parts of the Indian coast (Menon, 1931 ; Chacko, 1950 ; Ganapati & Murthy, 1955 ; Prasad, 1958).

Cyanophyceae : The blue-green algae *Trichodesmium erythraeum* and *Trichodesmium thiebautii* occurred in small numbers and they were present in the plankton only during December-April.

Dinophyceae : The dinoflagellates did not constitute a significant part of the phytoplankton in the tow-net collections and they were by far less numerous than the diatoms. It is likely that some of the smaller unarmoured forms might have escaped through the meshes of the net.

The seasonal distribution of the dinoflagellates which was more or less similar at all the sampling stations is shown in Fig. 4. The dinoflagellate maximum was noticed during September-November following the diatom maximum except at Chendia in 1956 where it was noticed in August coinciding with the diatom peak. The dinoflagellates were practically absent in summer and early south-west monsoon season.

Ceratium massiliense and *Dinophysis miles* were the two most important forms occurring in the tow-net collections. The former was found in the plankton in all the years studied. The latter was present in small numbers along with *C. massiliense.* But in December 1954 and November 1955 it was found to be more predominant than *C. massiliense. C. massiliense* appears to be a euryhaline form, occurring in salinity range of 10.78-33.72‰ whereas *D. miles* is stenohaline occurring only in high salinity conditions (32.67-33.42‰). Both the species thrive well when the sea water temperature ranged from 25.1-27.6°C. The paucity of *D. miles* during November-December of 1956 and 1957, in spite of favourable salinity conditions (30.94-35.0‰) appears to be due to water temperature remaining high (27.0-29.50°C.).

ZOOPLANKTON

A remarkable uniformity in the seasonal fluctuations of the total zooplankton as well as its main constituents is observed over the coastal stretch investigated (Fig. 5-7). The zooplankton (Fig. 5) exhibited a bimodal curve with peaks occurring during March-May and August-November. The main peak of the zooplankton production, however, occurred during the latter half of the south-west monsoon and early north-east monsoon seasons (August-November).

Within this period of zooplankton maximum two successive phases were also noticed, a first rather brief phase in August-September comprising a heavy growth of *Noctiluca miliaris* followed by a longer phase in which the copepods and the cladocerans predominated. The zooplankton concentration as a whole along this coast was markedly less in 1957 than in 1956.

A short account of the ecological relationship of the more common elements of the zooplankton in the North Kanara coastal waters is given below.

Noctiluca miliaris : The occurrence of this organism and its relation to the hydrological factors have been reported elsewhere by the author (1965).

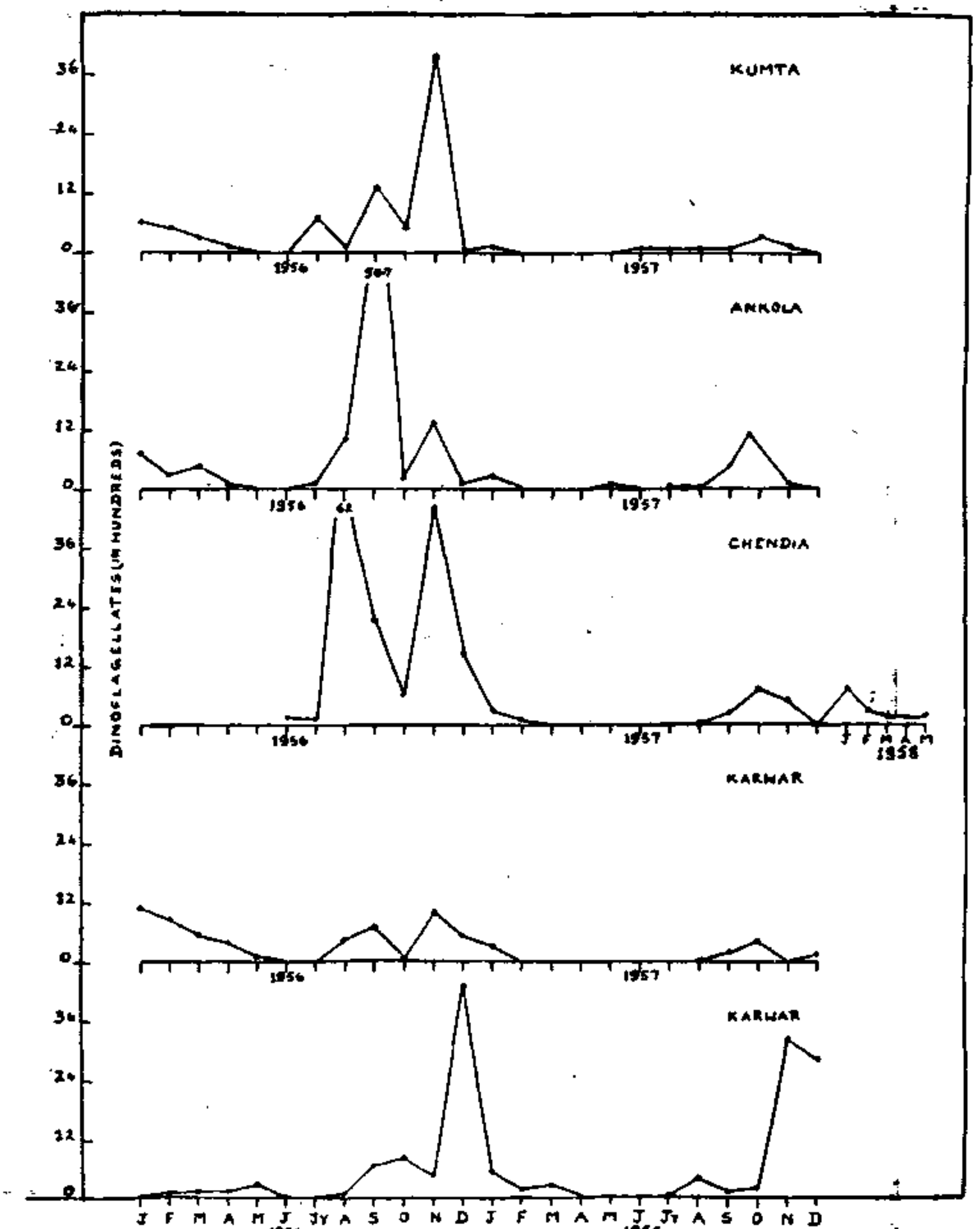

FIG. 4. Seasonal variations of dinoflagellates in the surface waters of the North Kanara coast.

TABLE III

*Seasonal variation of the zooplankton organisms in the North Kanara coast**

Name of the organisms	J	F	M	A	M	J	JY	A	S	O	N	D
	Months											
PROTOZOA												
Noctiluca miliaris	r	r	-	r	f	f	f	a	a	c	r	-
Foraminiferans	-	-	-	-	-	c	c	-	-	-	-	-
Radiolarians	f	r	r	-	-	-	-	-	-	r	r	f
Tintinnids	r	r	f	f	f	r	r	r	r	r	r	r
COELENTERATA												
Amphinema dinema	r	-	-	-	-	-	-	-	r	r	r	r
Obelia ,, ,, ...	r	r	r	-	-	r	r	r	r	r	r	r
Phortis	r	r	r	-	-	-	-	-	-	-	r	r
Irenopsis	r	r	r	-	-	-	-	-	-	-	r	r
Octocanna	r	r	-	-	-	-	-	-	-	-	r	r
Aequorea	r	r	-	-	-	-	-	-	-	r	r	r
Liriope tetraphylla	r	r	r	r	r	-	-	-	-	r	r	r
Solmundella bitentaculata ..	-	r	r	r	r	-	-	-	-	-	-	-
Siphonophora	r	r	r	r	r	r	-	-	r	r	r	r
Pleurobrachia globosa	r	r	r	r	r	-	-	-	r	r	r	r
Beroe	r	r	-	-	-	-	-	-	-	-	-	-
CHAETOGNATHA												
Sagitta enflata	r	r	r	r	r	r	-	-	-	r	r	f
S. bedotei	r	r	r	f	f	r	r	r	r	r	r	r
S.robusta	r	r	r	r	r	-	-	-	-	r	r	r
S.tenuis	-	-	-	-	r	r	r	-	-	-	-	-
S.neglecta	-	-	-	-	-	-	r	r	r	r	r	r
Krohnitta	-	-	-	r	r	-	-	-	-	-	-	-
ARTHROPODA												
Evadne tergestina	f	f	r	r	-	-	r	f	a	c	f	f
Penilia avirostris	f	f	f	-	-	-	-	r	f	f	a	f
Acrocalanus	f	f	c	c	c	f	f	f	c	a	c	f
Paracalanus	f	f	f	c	f	f	f	f	f	c	f	f
Eucalanus	r	r	r	r	r	r	r	-	-	f	r	r
Centropages furcatus	r	r	r	r	r	-	-	-	r	f	r	r
Pseudodiaptomus	f	f	f	f	f	r	r	r	r	r	c	c
Schmackeria	f	f	f	f	f	r	r	r	r	r	f	f
Temora	f	f	f	f	r	r	-	-	r	f	c	f
Labidocera	f	r	r	r	r	r	-	-	-	r	r	f
Acartia	r	f	r	c	f	r	r	f	c	f	f	r
Oithona	f	r	f	c	f	r	r	f	c	c	c	f
Oncaea	f	r	r	-	r	-	r	-	-	-	f	f
Corycaeus	f	f	f	f	r	f	r	r	r	r	c	f
Euterpina acutifrons	r	f	f	f	r	r	r	r	r	f	r	r
Macrosetella	-	r	r	r	-	-	-	-	-	-	-	-
Microsetella	r	r	r	r	-	-	-	-	-	-	-	r
Ostracoda	-	r	r	r	r	-	-	-	-	-	-	-
Schizopoda	-	-	-	-	-	-	r	r	r	-	-	-
Amphipoda	-	-	-	-	-	r	r	r	r	r	-	-
Lucifer	r	r	r	r	-	-	-	-	r	r	r	r
MOLLUSCA												
Pteropoda	r	r	r	-	-	-	-	-	f	r	r	r
TUNICATA												
Appendicularians	f	f	f	r	r	r	r	r	r	f	f	f
Salps (Doliolids)	-	-	-	-	-	-	-	r	-	-	f	-

TABLE III—(*Contd.*)

Name of the organisms	J	F	M	A	M	J	JY	A	S	O	N	D
LARVAL FORMS												
Actinotrocha	r	r	r	-	-	-	-	-	-	-	-	r
Cyphonautes	r	r	r	r	r	r	-	r	r	r	r	r
Brachiopod	r	r	r	r	r	r	r	-	-	-	-	-
Polychaete	r	f	f	f	f	r	r	r	f	f	f	r
Copepod nauplii	r	r	f	f	f	r	f	f	f	r	r	r
Cirripede larvae	r	r	r	r	r	r	f	f	f	f	f	r
Decapod larvae	f	f	f	c	f	f	r	r	r	f	f	f
Bivalve larvae	r	f	f	f	r	r	r	r	f	f	f	f
Gastropod larvae	r	r	f	f	r	r	r	-	r	r	f	r
Plutei	r	r	r	r	r	r	-	-	-	-	r	r
Fish eggs and larvae	r	r	r	r	r	r	r	r	f	f	f	r

*The symbols used against the forms denote as follows:
r = rare = < 10 per ml.
f = few = 10-100 ,,
c = common = 100-500 ,,
a = abundant = > 500 ,,
- = not recorded.

TABLE IV

Meteorological and hydrological conditions and Evadne tergestina *and* Penilia avirostris *during* 1954-1957

	Evadne (Maximum)	*Evadne* (Minimum)	*Penilia* (Maximum)	*Penilia* (Minimum)
Rainfall in cms. in the preceding month	25.0-50.0	0-5.0	2.0-15.0	30-100
Surface temperature in °C. ..	26.0-27.6	28.5-32.4	26.5-28.0	28.5-32.4
Salinity in ‰ ..	16.17-30.94	33.00-35.91	29.00-33.56	11.13-30.69

be due to intense feeding on the zooplankton by the pelagic fishes of this coast, which occur chiefly during October-February.

As in the case of the chaetognaths and the cladocerans there is a resemblance in the seasonal distribution of the copepods also between the North Kanara coast and the Malabar coast. In the latter, however, George (1953) found that the copepods were fairly abundant during September-May exhibiting a single peak unlike in the North Kanara coast where this group showed two well-marked peaks in its development within this period.

Meroplankton: Though the presence of the larvae in the plankton all the year round would suggest that breeding takes place throughout, a well-defined periodicity in breeding is indicated by the occurrence of the different types of larvae in the plankton as shown below.

Polychaete larvae	:	February-May and September-November.
Cirripede larvae	:	July-October.
Copepod larvae	:	March-May and July-September.
Decapod larvae	:	October-April.
Molluscan larvae	:	February-May and September-December.
Fish larvae	:	September-November.

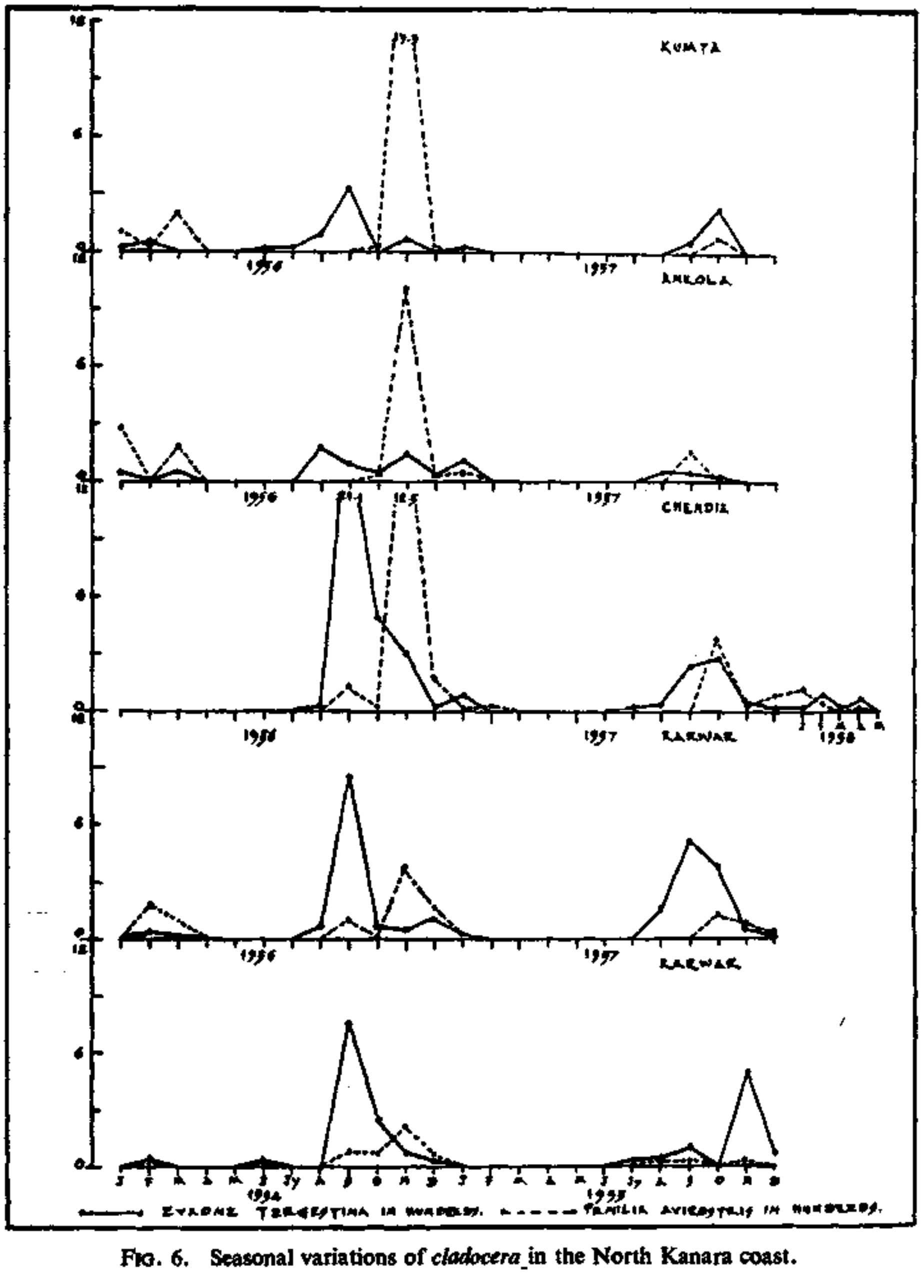

FIG. 6. Seasonal variations of *cladocera* in the North Kanara coast.

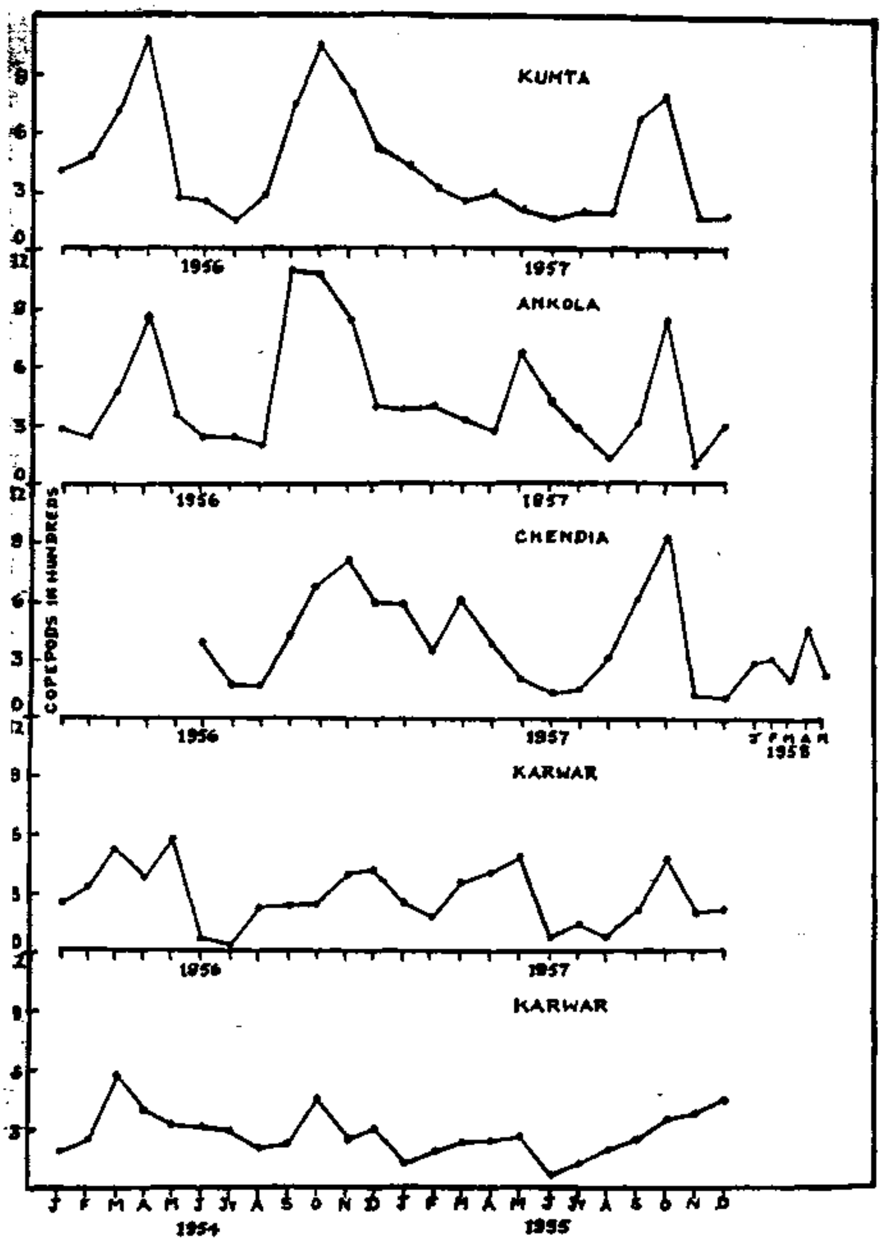

Fig. 7. Seasonal variations of copepods in the North Kanara coast.

Thorson (1950) views that only in temperate waters a well-marked periodicity in breeding occurs. The present results support the findings of Galstoff (1934) who has reported a definite periodicity in breeding in both the warm and cold seas.

As seen from the occurrence of the larvae in the coastal waters of North Kanara, February-May—a period of high temperature and salinity (28.0-31.7°C. and 32.0-35.76‰ respectively) is the favourable period for breeding of most of the forms except the cirripedes and fishes whose larvae were found in larger numbers during the monsoon and immediate post-monsoon months. The lowering of the salinity (3.08-24.66‰) and temperature (24.8-26.0°C.) in the monsoon period has probably stimulated breeding in these animals. The copepod larvae occurred in fairly large numbers under conditions of both high temperature and salinity and low temperature and salinity. In this case, the availability of food in the form of diatoms appears to be a controlling factor as seen from their larval abundance coinciding with the diatom maxima.

Food of Mackerel and Oil Sardine in Relation to Plankton

The analysis of the stomach contents of mackerel revealed that diatoms (*Fragilaria oceanica*, and species of *Coscinodiscus*, *Rhizosolenia*, *Chaetoceros*, *Bellarochea*, *Biddulphia*, *Thalassiothrix* and *Nitzschia*), dinoflagellates (species of *Prorocentrum*, *Dinophysis*, *Ornithocercus*, *Peridinium*, and *Ceratium*), Copepods (species of *Acrocalanus*, *Paracalanus*, *Acartia*, *Temora*, *Pseudodiaptous*, *Oithona* and *Euterpina*) and cladocerans (species of *Evadne* and *Penilia*) formed the main bulk of the diet (Tables V & VI). All these items were encountered almost throughout the year, the dominant composition of food depending on the seasonal abundance of the various planktonic elements (vide Tables I and III) which supports the observations of Bhimachar and George (1952).

TABLE V

Monthly mean occurrence in numbers, of the major groups of food organisms per ml. of the standardised sample of the stomach content of mackerel

Month	Vol. of gut content in ml.	Diatoms	Dinoflagellates	Tintinnids	Copepods	Cladocerans	Crustacean larvae	Molluscan larvae
January	1.0	60	80	14	35	10	5	—
February	1.0	50	50	10	20	5	3	—
March	1.5	200	35	20	50	2	4	5
April	1.2	150	20	—	30	—	6	2
May	0.8	80	5	—	15	—	*	*
June	0.5	120	10	—	21	—	*	—
July	1.2	7500	30	—	40	—	5	—
August	1.0	2800	50	—	35	8	3	—
September	1.0	120	205	—	60	40	3	*
October	2.0	90	350	10	80	65	5	8
November	2.2	70	150	18	75	55	12	5
December	1.6	50	100	30	45	15	8	2

*Denotes presence

The oil-sardine was found to be predominantly a phytoplankton feeder, the diatoms (species of *Coscinodiscus*, *Chaetoceros*, *Bellarochea*, *Fragilaria* and *Thallasiothrix*) forming the principal item of diet. Dinoflagellates (species of *Peridinium* and *Ceratium*) were also noticed to occur. The zooplankton portion of food was meagre, consisting of tintinnids, copepods, cladocerans and crustacean larvae. No definite relationship could be drawn between the food of oil-sardine and plankton since the fishery was irregular.

TABLE VI

Monthly mean percentage composition of the food components by points method

Month	Diatoms	Dinoflagellates	Tintinnids	Copepods	Cladocerans	Crustacean larvae	Molluscan larvae	Others
January	5.5	11.0	1.8	58.3	13.9	9.2	—	0.3
February	7.8	11.7	2.3	56.4	11.7	9.6	—	0.5
March	14.8	3.7	2.3	66.6	2.2	6.0	3.7	0.8
April	19.4	3.9	—	58.2	—	15.6	2.6	0.3
May	25.8	2.6	—	71.4	—	—	—	0.2
June	26.6	3.3	—	69.7	—	—	—	0.7
July	89.5	0.6	—	8.8	—	1.0	—	0.1
August	76.0	2.3	—	17.1	2.8	1.4	—	0.4
September	5.5	13.8	—	49.5	27.5	2.8	—	0.9
October	2.8	16.1	0.4	44.7	29.5	3.1	2.4	1.0
November	2.5	8.1	1.0	48.2	28.6	8.6	1.8	1.2
December	3.4	10.2	3.2	55.0	15.2	11.0	1.7	0.3

FISHERY IN RELATION TO PLANKTON

The monthly fluctuations of the mackerel and oil-sardine fishery at Karwar together with the nature of availability of plankton can be seen from Table VII. It is evident from the Table that there is no correlation between the abundance of the plankton and the fishery, since the fishery was noticed to be poor even when the plankton was rich. It is also interesting to note that whenever the fishery for oil-sardines was observed, it was long after the blooms of *Fragilaria oceanica* (blooms noticed during July-August except in 1957) subsided. The availability of this diatom has been found to influence the fishery in the Malabar coast (Nair and Subrahmanyan, 1955) since it formed a favourite food item of oil-sardines.

FISHERY IN RELATION TO HYDROLOGICAL CONDITIONS

The mackerel fishery season (October-February) represents the transition period from the low salinity and temperature conditions prevailing in the coastal waters during the south-west monsoon period (3.08-9.70‰ and 24.8-26.0°C. respectively) to the high salinity and warmer conditions in summer (33.2-35.76‰ and 29.0-31.7°C. respectively). During the period of active fishery the salinity and temperature ranged from 26.02-35.10‰ and 26.4-28.1°C. respectively and these conditions appear to be favourable for the fishery.

The oil-sardine fishery was irregular (Table VII). However, during the period of active fishery the surface salinity and temperature fluctuated between 22.2-34.53‰

TABLE VII

*Fluctuations in the mackerel and oil-sardine landings in metric tons and plankton volume in ml. during 1954-1957**

Month	1954			1955			1956			1957		
	Mackerel	Oil Sardine	Plankton volume	Mackerel	Oil Sardine	Plankton volume	Mackerel	Oil Sardine	Plankton volume	Mackerel	Oil Sardine	Plankton volume
January	90.3	—	P	6.2	105.0	P	69.7	—	P	121.4	0.50	P
February..	6.9	—	P	8.4	34.8	P	3.5	—	P	45.6	0.22	P
March	2.2	—	P	—	17.45	P	14.8	—	R	10.8	—	P
April	—	—	R	—	13.96	P	—	—	R	0.01	21.88	P
May	—	—	R	0.01	3.77	P	—	—	P	0.01	6.03	R
June	—	—	P	—	1.28	P	—	—	P	—	4.35	P
July	0.01	—	P	0.01	—	P	0.08	—	R	—	0.74	R
August	—	—	P	0.01	—	P	1.31	—	R	—	—	R
September	0.08	—	R	0.81	0.03	P	0.16	—	R	—	4.6	R
October	0.70	—	P	215.9	—	P	133.1	—	R	30.3	0.09	R
November	790.0	0.65	P	132.8	0.01	R	57.1	8.0	R	1177.0	—	P
December	163.7	2.70	P	77.9	—	R	18.6	26.3	P	990.8	—	P

Symbols used denote as follows:
P = poor < 10 ml.
R = rich > 10 ml.

and 26.8-30.3°C. respectively which is suggestive of tolerance of a wider range of these factors, compared to mackerel.

Discussion

A striking uniformity in the seasonal fluctuations of the phyto- and zooplankton organism over the entire coastal area investigated has been revealed from the present study.

The changes that take place in the hydrological characteristics of the coastal waters viz., lowering of temperature and enrichment of the plant nutrients (for details vide Ramamurthy, 1963) appear to be responsible for the primary production in July-August comprised of *Fragilaria oceanica*.

In temperate regions a total depletion of the nutrients is reported during the spring diatom outburst which acts as a limiting factor for primary production (Harvey, 1957). Such a clear cut inverse relationship does not occur in Indian waters (Prasad 1956 and Subrahmanyan, 1959). The overall range in the concentration of the various nutrients, studied in the present account, at the time of the diatom abundance (May-September) and at other times has been tabulated (Table VIII). Among these nutrients, nitrites showed total depletion. It was also observed that the maximum value for this nutrient (3.59 μg. at./1) noticed in July was much higher

TABLE VIII

Range in the concentration of the nutrients

Nutrient	May-September	Other period
Phosphates μg.at. L	0.20-1.78	0.22-2.42
Nitrites μg.at. L	0.0 -3.59	0.0 -0.69
Silicates μg.at. L	2.0 -49.0	2.0 -26.8

than that (0.69 μg.at./L) noticed at other times. The nitrites suffered rapid depletion during August-September following the diatom peak and remained so till November. Thus there has been a dearth of this nutrient following the primary production, unlike phosphates and silicates. However, it may be stated that the present observations being limited to nitrites, investigations on other nitrogenous compounds are necessary to elucidate the role of this element as a limiting factor in primary production.

It has been observed that the zooplankton production is closely related to diatom production. The zooplankton increases in numbers and attains the peak during August-November closely following the period of the diatom peak.

The relationship between the zooplankton and diatoms in this coast may thus be described as direct in the initial stages which becomes subsequently inverse. The rise in the zooplankton coincides with a marked depletion in the diatom population brought about obviously by the intense grazing of the herbivores. This is further supported by the fact that the net collections made at this time contain large numbers of greenish faecal pellets of zooplankton resulting from feeding on the diatoms.

The grazing effect of the herbivorous zooplankton would thus appear to be an important factor in regulating the plant crop.

The phyto- and zooplankton composition and their seasonal fluctuations in the North Kanara coast are observed to be more or less similar to those of the Malabar coast. This suggests that these regions constitute a common ecosystem governed perhaps to a very large extent by the upwelling during the south-west monsoon period, which is observed by Sastry (1959) to take place in the south-west coast of India. The same process would seem to influence the coastal waters of North Kanara as well (Ramamaurthy, 1963).

Though the food of mackerel is constituted by plankton, the abundance or paucity of this fish is not related to the plankton density which supports the findings of Steven (1949). The mackerel fishery was observed to occur under low temperature and normal salinity conditions (26.4-28.1°C. and 26.02-35.10‰ respectively). It is of interest to note that during the south-west monsoon period, even though the temperature was low, the mackerel shoals did not appear in the inshore area because of low salinity condition.

As will be seen from the temperature variations at the different centres in the North Kanara coastal waters (Table IX) upwelling in 1957 appears to be steadier than in 1956. As is well-known, upwelling is related to the wind conditions. In 1957 the winds were much stronger than in 1956, thereby effecting a stronger and more continuous upwelling than in 1956. It is significant that in the 1957 mackerel season bumper catches were made. It is known that upwelling would favour a rich plankton production. However, in 1957, the plankton was comparatively poor which may be attributed to removal by the plankton feeders. Since the concentration of mackerel in the inshore waters does not seem to be in direct response to the availability of plankton, as has been observed elsewhere in this account, the importance of upwelling appears to be more in creating temperature conditions conducive for the mackerel shoals to appear, after the warm summer months. Johansen (1925), Jensen (1930) and Jackman and Steven (1955) have stressed the importance of temperature and salinity in the movements of the mackerel in temperate waters. The present observations also bring out the importance of temperature and salinity, although the fluctuations of the former may not be as pronounced as in temperate waters, as factors to be reckoned and pursued for establishing a clearer picture of their relation to the fishery. In this connection, it may be pointed out that Pradhan and Reddy (1962) have stressed the importance of temperature and salinity conditions to explain the fluctuations in the abundance of mackerel.

In the case of oil-sardine, the fishery was noticed to occur in salinity and temperature conditions of a wider range.

SUMMARY

The present study relates to the observations on the plankton at four inshore stations along the North Kanara coast. The seasonal variations in the standing crop of plankton, total phytoplankton and zooplankton and their important constituents have been dealt with.

The south-west monsoon season and the immediate post-monsoon period (July-November) were found to be the most productive period for plankton. The

TABLE IX

Monsoon surface temperature fluctuations in the North Kanara coast during 1956 and 1957 and mackerel fishery

Chendia		*Ankola*		*Kumta*		Remarks
Date	Temperature °C.	Date	Temperature °C.	Date	Temperature °C.	
(1)	(2)	(3)	(4)	(5)	(6)	(7)
14-6-56	28.5	11-6-56	28.0	13-6-56	29.0	No upwelling
						→ Sudden fall in temperature and Probable commencement of upwelling.
12-7-56	25.0	19-7-56	25.3	25-7-56	24.5	
27-7-56	27.8	31-7-56	28.0	8-8-56	25.4	Wind velocity
9-8-56	24.6	16-8-56	25.4	23-8-56	28.5	Ranged from 1.4 to
28-8-56	25.4	30-8-56	25.4	31-8-56	26.5	4.8 knots/hr. during
6-9-56	26.0	10-9-56	27.4	12-9-56	27.0	June-September.
20-9-56	23.0	24-9-56	25.0	26-9-56	26.2	
18-10-56	28.2	22-10-56	27.6	30-10-56	27.8	→ Mackerel appears
27-3-57	28.7	3-4-57	30.2	23-3-57	29.0	→ Mackerel disappears Total catch 403.1 m.tons.
5-6-57	31.0	6-6-57	29.0	8-6-57	29.0	No upwelling
						Sudden fall in temperature and
		3-7-57	28.6			→ Probable commencement of upwelling.
13-7-57	27.0	19-7-57	27.0	26-7-57	27.0	
30-7-57	26.3	5-8-57	28.0	9-8-57	27.0	Wind velocity ranged from 5.4 to 10.8 knots /hr. during June-September.
17-8-57	25.5	19-8-57	26.0	27-8-57	25.0	
31-8-57	26.4					Total catch 1515.3 m. tons
17-9-57	26.2	9-9-57	26.3	12-9-57	26.0	
30-9-57	26.0	27-9-57	28.0	27-9-57	26.0	→ Mackerel appears
10-10-57	27.8	11-10-57	28.3	15-10-57	28.4	→ Mackerel disappears
7-2-58	28.8	—	No Data	—		

inorganic phosphates and silica do not appear to limit the primary production. Nitrites seem to exert an influence on the diatom production. The grazing effect of the herbivorous zooplankton is also an important factor in regulating the plant crop.

The ecological relationship of certain of the phytoplankton and zooplankton organisms have been discussed. The plankton characteristics of the North Kanara coast are compared with those of the Malabar coast.

The food of mackerel and oil-sardine and the fishery in relation to plankton and hydrological factors have been dealt with.

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