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RESEARCH BOOK ON
HYDROLOGY OF THE SHELF WATERS OFF KARNATAKA COAST

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PREFACE

Studies on Sea-water are very 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 seawater play an important role in determining the productivity of the sea water.

Monsoon plays a critical role in triggering environmental features such as Seawater temperature, salinity, disolved oxygen content and nutrient generation which In turn become responsible for the production of phytoplankton and zooplankton. An attmpt is made here to correlate certain environmental features with the abundance and fluctuations in phytoplankton and zooplankton in the shelf waters off Karnataka coast.

- **Dr. Rajendra Vishnu Salunkhe**

Acknowledgement

I take this apportunity to give my sincere previlage to my research guide, the distinguishing hydrologist Dr. Gopalkrishna Bhat, Department of Marine Biology and Research Institute, Karwar, Dist. Uttar Kannada, Karnataka University, Dharwad for suggesting me this topic. Words are inadequate to express my thanks towards him whose efficiency, nobiity and sincerity of tireless working which always inspired me. It is my great pleasure to work on the shelf waters off karnataka coast under his guidance. I always debited for his affectionate and friendly cooperation. Sincere thanks are also due to the Director of National Institute of Oceanography, Goa that they had given me a good apportunity of a research vessel Gaveshani Expedition No. 208.

My sincere thanks thanks to Mr. Harshwardhanji Patil, Ex MLA, Co-operative Minister, Maharashtra state and Chairman, Indapur Taluka Shikshan Prasarak Mandal, Indapur for his affectionate cooperation. It is my duty to express most sincere gratitude to my friends and staff colleagues of Arts, Science & Commerce College, Indapur especially Dr. Sandip Shinde for cooperating me in a technical way.

It is beyond my reach to find the proper words of affection towards my family members, my mother Pushpalata, beloved wife Savita, sons Abhishek and Atharv, daughter in law Dipti and grand daughter Yuvradni, due to them I ever get encouragement to do the work on different enthusiastic activities.

- **Dr. Rajendra Vishnu Salunkhe**

Dedicated to my

Late father Vishnu Ganpati Salunkhe

Ex-Subhedar, 18 Maratha Light Infantry

Indian Army

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INTRODUCTION:

R. V. Gaveshani Cruise No. 208 was carried to investigate the hydrography of the Karnataka coast. With the existence of six major estuarine systems namely, kali at north most, Gangavali, Aghanashini, Sharavati, Bhatkal, Koondapur and at southern Netravati. Though the influence of these on the fairly high fish production of Karnataka is understood, a systematic study to investigate the different abiotic and biotic factors was lacking long since. The present work is an effort to fill the lacuna besides to obtain a baseline data exclusively for the shelf and deep waters off Karnataka Coast (from Netravati to Karwar).

Arabian Sea is the main area for the exchange between Sea and estuary. The shelf region off Karwar is one of the important shrimp trawling areas of the west coast of India; hence it was considered worthwhile to study the hydrography of this area and its variation with Seasons.

Environmental factors play a vital role in the productivity of the Sea. Prevalence of the favourable hydrographical conditions is a prerequisite for optimum primary and secondary productions on which depends the fish production. The role of nutrients in limiting the distribution and abundance of plankton on which the fish thrive is also well understood. Since the coastal waters of North Kanara support an important fishery for the Indian mackerel. Karlier investigation at karwar (Noble, 1968; Ramamurthy, 1963; Annigeri, 1968, 1872, 1979) and Mangalore (Radhakrishnan, 1978; Venkataswamy Reddy, 1986; Hariharan, 1980) have contributed to our knowledge of the hydrological conditions off Karnataka Coast.

Generally subsurface water temperature is lower than the corresponding temperature decreases as depth increases. Heat budget processes which regulate the mixed layer temperature cannot obviously influence the temperature at the depth in the upper thermocline cooling of water can causes by the surface heat exchange processes at this depth is a remote possibility (Rao, 1989).

Penetration of light to the bottom is a function of depth circulation (particles in suspension) and phytoplankton production as plankton particles also are light scatters. Degree of penetration in the water changes with the diurnal position of the sun, the Seasonal inclination of the sun and the amount of cloud cover, turbulence, molecules processes in the water body. Transparency can affects by sediment churning up by strong tidal currents (Varkey, 1976; Sreekumar Nair, 1987). Turbidity lowers the efficient co-efficient. Increased turbidity of the water brought about by the land drainage during the preceding monsoon Season.

Generally salinity increases as depth increases. Salinity values are useful to identify the movement of water masses thoughout the complex. Rao and George (1960) stated that the salinity distribution in ostuaries can controls by ride. At many instances the sub-surface waters were highly saline and less oxygenated.

Dissolved oxygen in the ocean, a non-conservative parameter is influenced both by physical and biological processes. The changes in the hydrological conditions of waters reflects by the climatic conditions. Upwelling and Sinking develops in along the in along the Cochin coast has been reported earlier by Sastry and Myrland (1960). Banse (1959) has regarded the prevailing current system and not the wind to be the main cause of the upwelling.

The work of D'Souza and Sastry (1973), a and D'Souza and Sastry (1971) pointed out that the surface water are found to be supersaturated with oxygen throughout the Arabian Sea, except in regions of intensive upwelling. The oxyty in the surface layer is nearly uniform, indicating effective mxing in this layer. Below the surface layer, a strong oxycline (layer in which oxygen decreases with depth) which coincides with the thermocline. The oxypleths in the oxycline trends to rise towards the Indian coast, studies revealed that the oxygen maxima are due to the transport of oxygen rich subtropical subsurface waters across the equator. The high oxyty of the deep waters has been attributed to the penetration of the water mass originating in circumpolar regions.

Based on the dissolved oxygen concentration or oxyty (Montgomery, 1969) the ocean may be diided into three layers, the upper and bottom layers of high oxyty separated by a layer of low oxyty. The upper layer being in contact with the atmosphere, is maintained at higher oxyty levels depending upon the oxygen solubility, while the bottom water whose origins could be traed to the Sea surface at high latitudes (and hence rich in oxyty at the fime of formation of the deep and bottom waters) retains most of its oxygen as the consumption of oxygen by the biological processes is very small at these levels. The intermediate layer oflow oxyty, often referred as the xygen minimum layer, is though to be the result of week motion by some investigators and as such it has been regarded by them as the layer of no motion, Someothers, however, believe that a combination of both physical and biological processes is responsible for the formation of the intermediate low oxyty layer.

Efficient co-efficient i.e, pH values are generally low after south-west monsoon and higher during September could be due to the increased turbidity of the water during the preceding south- west monsoon.

Chlorophyll concentration decides the primary productivity in the Sea. The regions away from the coast, higher concentrations of suspended matter are presumably due to a greater plankton production. In the coastal regions, suspended matter increases, by Krishnamurthy (1976).

The transformation of inorganic matter into organic matter byphotosynthesis to form plant material is the most important single facter governing the productivity of any region in the Sea. In fisheries research, the estimation of organic production of an area gives a better understanding of the contidions affecting the production in fish. Pratt and Berkson (l.C.) have observed that the development of phytoplankton bloom increases the surface available to bacteria and the activity of the bacteria in turn increases the rate of supply of nutrients to the photosynthetic production. Studies undertaken on the production and distribution of these materials in different water masses (Rao and Rao, 1975) indicate wide fluctuations in particulate organic contents depending on the Seasons and geographical location.

Study of particulate suspended matter in Sea water is important in understanding

1) Genesis of sediments in oceans,
2) Transport and dispersal of suspended material into a basis,
3) Relative contribution of terrigenous, volcanogenous, biogenous and chemogenous material to suspended matter and variation its concentration at different depths.

Study of particulate matter is also important for forecasting the fisheries of a particular region as the partivulate matter forms food for a large variety of marine life. Lisitsyn[1], Gordeev[2], and serova[3], have studied the distribution and composition of suspended matter in the Indian Ocean, but their studies did not cover the continental margin. Main source of suspended matter in the ocean are river run-off, biological productivity and eolian dust.

As the plant life much depends on the concentrations of the nutrients, it is of much value to study the distribution, inter-relations and fluctuations of nutrients in the Sea. The nutrients are essential for the growth of phytoplankton and lack of these would act as a limiting factor. Generally concentration of nutrients in higher in bottom than surface water. In the esturine region, the nutrients like nitrate and ammonia remained higher than those in the coastal waters. The nutrients determine the potential fertility of the waer masses (Harvey, 1955) and therefore it is important to have an idea about their distribution and behavior in different geographical locations and Seasons. There are increasing evidences to show that besides inorganic nutrients, organic compounds of nitrogen and phosphorus in solution are also actively involved in the growth of marine phytoplankters (Guillard, 1963; Harvey, 1953). Yet only limited information in available on the distribution of organic nitrogen and dissolved orgenic phosphorus in the inshore and the estuarine waters of India (Rajendra and Venugopalan, 1973; Rao and Rao, 1974; Qasim and Sen Gupta, 1981).

The nitrogen cycle in the Sea exhibits a course closer to that of phosphorus. Harvey (1955) and Sverdrup *et al.* (1942) stated that the distribution of nutrient in the Sea is the final condition brought about the by lateral currents, vertical eddy diffusion and the downward movement due to cycle of biological events.

Concentration of inorganic nitrogen compounds within the euphotic zone is very low and it increases in the thermocline layer. The shallow nitrite maximum whth low nitrite cccurs in the surface layer nearly the h=thermocline with a relatively high dissolved oxygen. Seasonal variations are related to the monsoonal cycle. The relation between salinity and nutrients suggest that the fresh water is a main source for the addition of nitrate to the extuary. Nutrients salts (phosphates and nitrates) appear to be independent of tidal effect. During the high biological active movement period, phosphorus value lowers. The concentration of macronutrients (C, N, P etc.) and micronutrients (Mn, Zn, Cu, Co etc.) in Sea water is non-conservative.

Brandt (1899) opines that both light and nutrient supply control metabolic activities of phytoplankton. Several other workers (Kreps and Verjbinskaya, 1930; Braarud, 1935) also showed that when nutrientrs are exhausted phytoplankton growth becomes inhibited. Riley (1946) has indicated a close correlation between the amount of phytoplankton and nutrients. Floristically, the phytoplankton abundance largely depends on nutrient level. The Phytoplankton assemblages of high tides were richer than the low tide. Generally effluent discharge point shows increased plankton production.

Peak concentration of the ammonia is related to the abundance of phytoplankton production, the production may be less relatively in polluted waters. The high values of nitrate-nitrogen may be due to bacterial oxidation rather than photochemical oxidation of the high level to ammonia. Since the rate of regeneration of nitrogen is slower than that of phosphorus, the readily available ammonical form of nitrogen may be responsible for high plankton production.

The coastal water usually harboure more zooplankton. Some times there may not be a clear- cut relationship discernible between phytoplankton and zoo-plankton, this may be due to the changing food habits of plankton in the coastal waters.

REVIEW OF LITERATURE:

Fairly good literature is available dealing with the environmental characteristics of shelf waters of Indian Ocean. Exclusive investigations on the chemical aspects of our waters are by R. Sen Gupta, Rajgopal and Qasim (1976), Premchand and Sastry (1976), R. Sen Gupta and S. Z. Qasim (1979), R. Sen Gupta and Naqvi (1984), Deflef Quadfasel and Kai Jancke (1985). The pioneer work on physical aspects are by Rama Raju and Somayajulu (1981), whereas Raghu Prasad and Ramachandran Nair (1973) have collected hydrographic informations during their investigation in the Indian fisheries. Distribution of phytoplankton and hydrographic regions were reported by Margaret Torrington- Smith (1974).

Hydrography of Andaman Sea have been worked out by Ramesh Babu and Sastry (1976). Chalpati *et al.* (1975) made a work on particulate organic matter. Study on planktonology by Hara *et al.* (1975), Rajashree Gounda and Pannigraphy (1989). Subbaramayya and Ramamohan Rao (1986) studies the variation of Sea surface temperature in the Bay of Bengal. Lakshmana Rao and Anita Pattnaik (1986) made a study of the physical features of an exposed sandy beaches at Gopalpur (Orissa coast). Hydrography of the Wadge bank in premonsoon and monsoon Season was investigated by Rama Raju, Narasimha Rao *et al.* (1989). Distribution of nitrate were reported by Panda *et al.* in 1989. Wind stress, curl and vertical velocity were studied by Babu *et al.* (1989).

Specific Investigation on the shoreward upsole of the layer of minimum oxygen off Bombay and its influence on marine biology especially fisheries are by Crruthers, Gogate *et al.* (1959). Study on dissolved oxygen at Malbarcoast by Kasturi Rangan (1957).

Significant observation on the chlorophyll and phosphate at Bombay harbor Bay is by Viswanathan and Krishanmurthy (1976), whereas study on distribution of suspended matter of north-western shelf of India have been worked by Rajamanickram and C. H. M. Rao (1976). Study on organic production of Gulf of Manner was made by Raghu Prasad and Ramachandran Nair (1963). Specific Observations on composition of bottom mud in relation to the phosphate cycle of Malbar coast were made by Seshappa and Jayaraman (1956).

Physico-chemical investigations at North-Arabian Sea are studied by S. W. D.'souza, Sankaranarayanan *et al.* (1983), Zingde, Sharma and Sabnis (1985), Rao and Hareesh Kumar (1989), while its effect on tolerance of gastropod and brown Seaweeds are studied by Swami and Karande (1987), Hiwale and U. H. Mane (1989), C. H. Kesava Rao and

Indusekhar (1989). Significant Observation on the light transmission characteristics are by Varkey and Kesavadas (1976).

Diurnal variation of some physico-chemical factors at Goa, at off Velsao, Mandovi estuary, Cumbarjua canal, Colva beach, Zuari river, were studied by Kurup *et al.* (1975), S. Y. S. Singbal (1976), Gangadhara Rao *et al.* (1976), Singbal *et al.* (1976), Verlencar and C.D'silva (1977), S.N.D'souza (1983), Verlencar (1987). Verlencar (1984) did studies on dissolved organic nutrients and phytoplankton production in the Mandovi estuary and coastal waters of Goa. Discolouration of water and its effect on fisheries along the coast was observed by Devassy and Sreekumaran Nair (1987), whereas Achuthankutty (1987) carriedout a comprehensive investigation on the commercially important Penaeid shrimp larvae in the estuaries of Goa.

Significant works on hydrological features of North Kanara inshore regions and offshore regions have been studied by Ramamurthy (1963), Noble (1968), G.G. Annigeri (1968, 1972, 1978, 1979), Reddy *et al.* (1978), Gopinathan and Joseph (1980), R. Sen Gupta, Analia Braganca *et al.* (1980), Zingde and Singbal (1983), whereas Ramamurthy (1966) have worked on the studies on the plankton of the North Kanara coast in relation to the pelagic fishery.

The pioneer works on the hydrological studies in the inshore waters of Mangalore, have done by Venkataswamy Reddy and Hariharan (1986), Radhakrishnan (1978), whereas hydrological conditions in the fishing grounds off South Kanara have studied by Benakappa *et al.* (1980) and Suresh (1977). Segar and Hariharan (1989) studied the Seasonal distribution of nitrate, nitrite, ammonia and plankton in effluent discharge area off Mangalore, while Venkataswamy Reddy and Hariharan (1964) made a study on the distribution of nutrients in the sediments of the Netravati – Gurpur estuary, Mangalore. Vishnu Bhat and Gupta (1984) made observations on the ingression and distribution of larval prowns in the Nethravati – Gurpur extuary.

Extensive literature on the hydrography related to the marine planktons along South-West coast of India are available by several worker (George 1953, Subrahmanyan 1959, Abidi, Desai *et al.* (1983). Sewell (1955) is one among the pioneer workers who studied the Sea coast of South-Arabia. The study on upwelling and bottom trawling off the South-West coast of India have worked by Banse (1959). Ramamirtham and Jayaraman (1960. 1963), George and Krishna Kartha (1963), recorded the hydrographical conditions around Cochin. The work on the influence of some hydrographical factors on the fisheries was carriedout by Sankaranarayanan and Qasim (1969). Rao *et al.* (1976), Satish and Shetye (1984) made observations on the Seasonal variability of the temperature field off the distribution of urea in the waters of west coast of India by Verlencar (1980). Specific study on physico-chemical features and energy input in three sandy beaches are of Wafar *et al.* (1980). Sarala Devi *et al.* (1983) studied the nutrients in some estuaries of Kerala. Studies on temporal and spatial variations in particulate matter, particulate organic carbon bution and abudance of phytoplankton at Vishakapatnam harbor was by subrahmanyam and Bhavanarayan (1989).

Specific investigation on the water masses and the frequency of soa water characteristics in the upper layers of the South-Eastern Arabian Sea are by Rama sastry (1959), whereas Banse (1959) has given a special report on upwelling and bottom trawling off the south-west coast of India. Hydrography of the Laccadive off-shore waters in a winter Season was studied by Patil and Ramamirtham (1963), while primary production of Seagrass Cymodoce a serrulata and its contribution to productivity of Amini atoll are by Kaladharan and Devid Raj (1989). Special investigation on oceanography of the Arabian Sea during south-west monsoon was by D'souza and Sastry (1973). Significant work on temperature distribution in the upper layers of the northern and eastern Arabian Sea during Indo-soviet monsoon experiment have studied by Ramesh Babu *et al.* (1975). Productivity studies in the south eastern Arabian Sea have been worked by Bhargava *et al.* (1978). Naqvi and Qasim (1983) carried out a comprehensive investigation on the inorganic nitrogen and nitrate reduction in the Arabian Sea.

Other exclusive investigations were made by many workers. Ecology of inland waters and estuaries was studied by (1961), whereas ecology of the tropical waters was by Ganapati (1960). Ketchum (1962), Sundararaj and Krishnamurthy (1979) worked on the relation between nutrients and plankton. Exclusive investigations were made by Qasim *et al.* (1968). They have worked on Fishery hydrography (Qasim 1963), solar radiation and its penetration in a tropical estuary (Qasim *et al.* 1968), Organic production in the tropical estuary (Qasim *et al.,* 1969).

MATERIAL AND METHODS:

A group work has been carried out by the department of Marine biology, to investigate the hydro biological features of the continental shelf area off Karnataka Coast, on board the Research Vessel Gaveshani, the Cruise No. being 208. The Cruise was undertaken during 10^{th} 20^{th} January 1989.

The vessel had left Mormugao port on 10^{th} January, 1989 and reached the first station at off Mangalore. The details of locations are given in cruise track (Fig. 1).

The sampling was done in eight transect across the shelf comprising of twenty five stations of which twenty three were in shelf waters and two in deeper waters off Mangalore. In these four were anchoring stations. The depths of stations varied from 17 to 1650 mtrs. 23^{rd} station was having maximum depth of 1650 mtrs. and seventh station was relatively shallow with a depth of 17 mtrs. Deep water samples were taken from 5 - 10 mtrs. above the bottom.

Water samples for the measurement of the different hydrographical parameters and nutrients were collected at every stations at two depths; surface and bottom water. Few samples were not analysed. Water samples were collected from two different depths and were utilised for the estimation of salinity, dissolved oxygen, suspended matter, chlorophyll a, nutrients such as nitrite, nitrate, phosphate etc., part of analysis was carried out on board the vessels. In additions, diurnal observations on secondary production were carried out at the anchore stations at 6 hourly interval. Surface water was collected by casella bottle. Bottom water collected by Niskin bottle. For planktonic secondary production, a zooplankton net was used.

The salinity determinations were made by Mohr's method. Wrinkler's standard method was followed for estimating dissolved oxygen. pH was determined by pH meter and pH paper. Nutrients were measured following the standard procedure given by Grasshoff (1976). Biomass was determined by displacement method.

Suspended load, planktonic primary production and planktonic secondary productive values were taken from Miss. Sangita and Miss. Sadhana - the participants of the Cruise. V.E.C. measured by a seechidisc. Temperature measurement was done by using thermometer. The data was compiled and results are presented in 7 chapters as detailed in the following pages.

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Table 1: The data, station number, co-ordinates and total depth is given as follows:

Date	Station No.	Coordinates: Latitudes & Longitudes	Depth (m)		Date	Station No.	Coordinates: Latitudes & Longitudes	Depth (m)
11/01/1989	1	12°43′.0 & 73°47′.0	1500		16/01/1989	14	13°59′.8 & 73°21′.8	200
11/01/1989	2	12°51′.0 & 73°58′.0	440		16/01/1989	15	14°00′.0 & 73°53′.0	59
12/01/1989 (anchor station)	3	12°48′.0 & 74°41′.0	40		16/01/1989	16	14°00′.0 & 73°24′.0	20
13/01/1989	4	13°06′.2 & 74°34′.9	35		16/01/1989 (anchor station)	17	14°16′.2 & 74°22′.3	17
13/01/1989	5	13°06′.0 & 74°00′.0	88		17/01/1989	18	14°12′.0 & 73°55′.0	57
13/01/1989	6	13°05′.7 & 73°41′.9	430		18/01/1989	19	14°12′.0 & 73°20′.0	65
13/01/1989	7	13°06′.6 & 73°22′.1	1650		18/01/1989	20	14°30′.2 & 73°20′.9	115
14/01/1989	8	13°24′.0 & 73°36′.1	200		18/01/1989	21	14°30′.0 & 73°53′.0	54
14/01/1989	9	13°24′.0 & 74°00′.0	63		18/01/1989	22	14°30′.0 & 74°15′.0	21
14/01/1989	10	13°24′.1 & 74°29′.9	30		18/01/1989 (anchor station)	23	14°49′.0 & 74°06′.4	7
14/01/1989 (anchor station)	11	13°36′.4 & 74°25′.7	37		19/01/1989	24	14°49′.0 & 73°35′.0	75
15/01/1989	12	13°35′.0 & 73°55′.0	64		12/01/1989	25	14°49′.0 & 73°08′.0	192
15/01/1989	13	13°35′.0 & 73°30′.0	107					

The data, station and number, co-ordinates total depth is given as follows:

Date	Station No.	Coordinates		Total Depth (Mtrs.)
		Latitudes	Longitudes	
11-1-1989	1	12° 43′	73° 47′	1500
11-1-1989	2	12° 51′	73° 58′	400
12-1-1989 (Anchor station)	3	12° 48’	74° 41’	40
13-1-1989	4	13° 06′	74° 34 .9′	35
13-1-1989	5	13° 06′	74° 00′	88
13-1-1989	6	13° 05′	73° 41 .9′	430
13-1-1989	7	13° 06 .6′	73° 22 .1′	1650
14-1-1989	8	13°24′	73° 36.1′	200
14-1-1989	9	13° 24′	74° 00′	63
14-1-1989	10	13° 24.1′	74° 29′	30
14-1-1989 (Anchor Station)	11	13° 36 .4′	74° 25 .7′	37
15-1-1989	12	13° 35′	73° 55′	64
15-1-1989	13	13° 35′	73° 30′	107
16-1-1989	14	13° 59.8′	73° 21 .8′	200
16-1-1989	15	14° 00′	73° 53′	59
16-1-1989	16	14° 00′	74° 24′	20
16-1-1989 (Anchor Station)	17	14°16 .2′	74° 22 .3′	17
17-1-1989	18	14° 12′	73° 55′	57
18-1-1989	19	14° 12′	73° 20′	65
18-1-1989	20	14° 30.2′	73° 20.9′	115
18-1-1989	21	14° 30′	73° 53′	54
18-1-1989	22	14° 30′	74° 15′	21
18-1-1989 (Anchor Station)	23	14° 49′	74° 06.4′	7
19-1-1989	24	14° 49′	73° 35′	75
20-1-1989	25	14° 49′	73° 08′	192

EXPERIMENTAL RESULTS:

The different hydrological parameters studied are temperature, salunity, pH, dissolved oxygen, V.E.C., nutrients such as phosphate, nitrate, nitrite alongwith suspended load, planktonic primary production and secondary production. What follows is a brief description of the respective values.

Temperature:

Temperature of surface water was ranging its minimum upto 26°C and maximum upto 30°C. Temperature of bottom water was ranging its minimum value upto 12°C to maximum upto 30°C, at an average of 28.07°C and 25.87°C respectively (Table-I-A). Temperature of bottom water varied to a greater extent with compair to the surface water.

Salinity:

Salinity of surface water ranged from 30.40% to 33.84% and of bottom water, it ranged from 30.74% to 35.85%, at an average of 31.60% and 32.36% respectively (Table-I-A). Bottom water salinity range was comparatively high.

Dissolved oxygen:

Higher and lower values of surface water being 0.67 ml at NTP/L and 7.79 ml at NTP/L. Higher and lower values of bottom water being 0.50 ml at at NTP/L and 7.45 ml at NTP/L, at an average value of 3.47 ml at NTP/L and 3.17 ml at NTP/L respectively (Table-I-B). Variation in dissolved oxygen values was drastic.

pH:

Hydrogen ion concentration of surface water was ranging from value of 7.5 to 9.02 and of bottom water was ranging from 7.5 to 8.94, at an average of 7.95 and 7,92 respectively (Table-I-B).

Suspended load:

It varied between 12.6 and 30.0 mg/L, at an average of 20.3 mg/L. It varied to a large extent (Table-I-B).

V. E. C:

The gvalue of vertical extinction coefficient varied between 0.1889 m and 0.0653 m at an average of 1.3813 m (Table-I-B).

Phosphate:

Phosphate value of surface water ranged from 0.261 ug/L to 0.044 µg/L and of bottom water it varied from 0.667 µg/ L to 0.11 ug/ L, at an average of 0.119 µg/ L and 0.140 µg/ L respectively (Table-I-C). Phosphate values varied to a lesser extent at both, surface and bottom waters.

Nitrate:

Nitrate value of surface water was ranging from 0.040 µg/L to 5.050 µg/ L and of bottom water, it was ranging from 0.042 µg/ L to 10.846 µg/ L, at an average of 0.842 µg/ L and 0.770 µg/ L respectively (Table-I-C). Variation in nitrate values was drastic at surface as well as at bottom water.

Nitrite:

Nitrite value of surface water varied between 0.071 µg/ L and 1.600 µg/ L and of deep water, it varied between 0.061 µg/ L and 3.815 µg/ L, at an average of 0.336 µg/ L and 0.604 µg/ L respectively (Table-I-C).

Planktonic primary production:

It was ranging from 0.60 mg/m^3 of chlorophyll 3 to 0.15 mg/m^3 of chlorophyll, at an average of0.36 mg/m^3 of chlorophyll (Table-II).

Planktonic secondary production:

For zooplankton production, higher and lower values being 99.04 mg/100 m^2 dry wt and 3 2165.50 mg/100 m^3 dry wt, at an average value of 3 644.82 mg/100 m^3 dry wt (Table-III). Planktonic secondary productivity values varied to greater extent.

Stationwise variation:

Stationwise variation in depth of sampling, temperature, salinity, dissolved oxygen, pH, V.E.C., suspended load, phosphate, nitrate, nitrite concentration, planktonic primary production values and planktonic productivity.

Secondary productivity values are given as below:

STATION 1:

a) Surface water was having temperature of 28°c but bottom water temperature showed only 26°c. It indicates that the temperature decreases as depth increases (Table-I-A).
b) Salinity value at surface water was 31.22% and at bottom it was 31.22%. That means, the salinity of surface and bottom water was more (Table-I-A).
c) Dissolved oxygen content was 5.92 ml at NTP/L at surface water and 4.74 ml at NTP/L at bottom water (Table-I-B). It was showing that the dissolved oxygen was decreasing as depth increasing. At bottom, it was showing less content of dissolved oxygen as compair to the surface water.
d) pH at surface water was ranged of 8.75 and at bottom, it ranged of 8.80 (Table-I-B). Generally pH decreases as depth increases but here it showed a slight inverse proportion.
e) Samples were not analysed for suspended load value.

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f) V.E.C. i.e, light transpenency was 0.1214 ml. It was showing slight turbid water (Table-I-B).

g) Phosphate content at surface water was 0.261 µg/L and at bottom water, the content was 0.165 µg/L (Table-I-C). At bottom water it was showing less phosphate content as compair to the surface water content. Phosphate content at surface water showed peak.

h) Nitrate value (NO_3) at surface water was showing 5.050 µg/ L and at bottom, the content was 10.84 µg/ L (Table-I-C). Bottom water was showing double nitrate content than the surface water content. Nitrate showed peak values for surface as well as for bottom water. This peak could not find at any other station. At this station only, both at surface water and at bottom water, the nitrate values were drastic than further stations.

i) Samples were not analysed for nitrite content at surface as well as at bottom water also.

j) Planktonic primary production ranged up to 0.30 mg/m^3 (Table-II).

k) Planktonic secondary productive value was 3 272.36 mg/100 m^3 dry wt (Table-III).

STATION 2:

a) Temperature of water was varying between 28°C and 25.7°C at surface and bottom water respectively.

b) Salinity was ranging between 31.44% and 31.66% at surface and bottom water respectively. Bottom water is comparatively highly saline than the surface water.

c) Bottom water is less oxygenated than surface water. At surface water, DO content in ml at NTP/L was 6.43 and at bottom water was 5.25.

d) At surface water pH was 8.61 and at bottom water it was 8.66. A slight reverse trend was observed here.

e) Here phosphate (Po) content at surface was 0.172 µg/ L and at bottom water, it was 0.200 µg L.

f) Nitrate content at bottom water, it showed enrichment of 1.814 mg/ L and at surface water it was 0.900 µg/ L.

g) Here also nitrite showed enrichment at bottom water of 3.815 µg/L and surface water, it was 1.600 µg/ L.

h) Planktonic primary production was very loss as compare to other stations at an range of 0.15 mg/m^3 of chlorophyll (Table-II). Planktonic secondary production ranged high upto 897.55 mg/100 m^3 dry wt (Table-III).

STATION 3A:

a) Temperature was showing slight reverse trend i.e. surface water was having temperature of 26°C and bottom water of 29°C.
b) Value of salinity showed 30.40% at surface water and 30.99% at bottom water. Salinity at bottom water showed more content than surface water. Salinity of surface water was very low as compair to the other stations.
c) Maximum dissolved oxygen content at surface water was 7.70 ml at NTP/L and minimum at bottom water was 7.45 ml at NTP/L, Bottom water showed highly oxygenated area.
d) Minimum pH at surface water was 8.68 and at bottom water, maximum pH was 8.86.
e) At surface water, phosphate content was 0.150 µg/ L and at bottom water, the content was 0.133 µg/ L. Phosphate content at surface, was more. It showed slight reverse trend.
f) Nitrate showed the high content at surface water of 0.814 µg/ L and low content at bottom water of 0.657 µg/ L. Here a roverse trond was observed.
g) Variation of nitrite content at surface water and bottom water was 1.171 and 1.057µg/ L respectively. Concentrations are found to be quite similar.
h) Planktonic primary production was less upto 0.25 mg/m^3 of chlorophyll (Table-II).
i) Planktonic secondary production was ranged of 928.50 3 mg/100 m^3 dry wt (Table-III).

STATION 3 B:

a) Temperature of surface water showed 27°C and bottom water showed 28°C. Bottom water was warmer than the surface water. Temperature was decreased for both water levels.
b) Salinity was increased for both water levels, surface water showed salinity of 30.74% and bottom water of 31.41%.
c) Dissolved oxygen at surface water was ranged up to 7.79 ml at NTP/L and bottom water of 6.60 ml at NTP/L. Here, DO value showed highest value of surface water that

could not find at any other station. Bottom water was having less oxygen value as compare to previous station i.e., station 3-A.

d) pH of surface water ranged of 8.70 and bottom water ranged of 8.94. pH of bottom water showed peak value. pH values were increased for both layers than the previous station i.e., station 3 A.
e) V.E.C. observed was very low of 0.0653m, could be due to turbidity.
f) Phosphate content showed very low concentration than previous station i.e., station 3 A. Surface water was having 0.094 µg/ L of phosphate content and bottom water was having 0.083 µg/ L of phosphate content.
g) As compare to the station 3 A, nitrate content at surface water showed less concentration i.c., 0.157ug/ L and bottom water showed high concentration i.e.,1.571 µg/L.
h) Nitrite concentration at surface water was 0.543 ug/L and at bottom water, was 1.357 µg/L. With comparing to station 3A, surface water showed less nitrite concentration and bottom water showed more nitrite concentration.

STATION 3 C:

a) Temperature for surface and bottom water was same .i.e., 28.5°C. Temperature was showing gradual increase, in anchoring station i.e., 3A & 3B station.
b) Salinity varied only between 30.66% and 30.74% at surface and bottom water respectively. 30.74% salinity was very low value at bottom water.
c) For dissolved oxygen, surface water and bottom water values being 6.85 and 6.52 ml at NTP/L. This station was showing less oxygenated water than previous two stations i.e., station 3A & 3B.
d) pH value ranged as 9.02 and 8.68 at surface and bottom water respectively. 9.02 pH value could not find any where. compare to previous two anchoring stations, surface water showed high pH value and bottom water showed less pH value.
e) Enrichment of suspended load was fould of 30.0 mg/L.
f) Phosphate has 0.072 and 0.100 µg/L respectively, the values of surface and bottom water. Surface water showed deficiency, at bottom water showed slight increase than previous stations 3A & 3B.
g) Nitrate content at both surface and bottom water was same i.e., 0.271 µg/L. Surface was showed increase and bottom was showed decrease than station 3A and 3B.

h) Nitrite valued of 0.342 μg/L and 0.171 ug/L at surface and bottom water respectively. Both values were showing deficiency than station 3A & 3B.

STATION 4:

a) Temperature was decreased at both layers 26 °C and 25.5 °C at surface and bottom water respectively. Bottom water was slight warmer than surface water.
b) Salinity at both layors didnot show any much variation. Surface water showed 31.25% less salinity and bottom water showed 31.50% high salinity.
c) Both layers have quite similar in dis solved oxygen content, variation at surface and bottom water was 5.75 and 5.58 ml at NTP/L. The values were less oxygenated than previous station 3C.
d) It showed both lower values at both layers than station 3C. pH of surface water was 8.0 and of bottom water was 7.50.
e) Suspended load was in low quantity of 19.7mg/L.
f) V.E.C. showed slight mid range i.e., 0.1214m.
g) This station was showing varying amount of phosphe content 1.0.- 0.127 μg/L at surface water and 0.016 μg/L at bottom wator. The concentration was increased at surface water and decreased at bottom water than previous station 3C.
h) (h) As compared to station 3C, this station was showing slight enrichment in nitrate concentration 1.0., at surface water, the concentration was 0.571 ug/ L and at bottom water, the concentration was 0.543 ug/L. Concentration exhibited a remarkable increase. Both concentrations are quite similar at surface as well as at bottom water.
i) There was vide variation at surface and bottom water nitrite concentration i.e., 0.628 μg/L and 0.061 μg/L at surface and bottom water respectively. The concentration at surface water was doubled and the concentration at bottom water was decreased doubled value of previous station i.e., 3C.
j) Planktonic primary production was comparatively less of 0.25 mg/m^3 (Table-II).
k) Planktonic secondary production was less upto 123.80 3 mg/100 m^3 dry wt (Table-III).

STATION 5:

a) Temperature was slightly higher at surface and bottom water as compared to station 4. Temperature was higher at surface water i.e., 29°C and lower at bottom water 1.0., 28°C.

b) Salinity at surface water was increased upto 31.58% than previous station 4 and salinity at bottom water was also increased upto 32.42% than previous station 4.

c) Both layers were less oxygenated. Dissolved oxygen at surface water was valued of 4.57 ml at NTP/L and at bottom water, it was valued of 4.40 ml at NTP/L. c) Bottom water was having less oxygen value than surface water.

d) pH at surface and bottom was same i.e., 7.75.

e) V.E.C. was comparatively low 1.c., 0.0850m.

f) Suspended load was in low concentration of 18.µg/L.

g) Phosphate concentration was having very lov at bottom water 0.011 ug/L and comparatively low concentration at surface water of 0.088 µg/L. Bottom water showed very low concentration than surface water.

h) Nitrate was comparatively low concentration than previous station 4. Surface water showed less concentration of 0.114 µg/L and bottom water, of 0.171 µg/L showed a slight high concentration.

i) Nitrite was showing irratic variation. Surface water low nitrite concentration was 0.142 µg/ L and bottom water high nitrite concentration was 0.285 µg/L.

j) Planktonic primary production was less showed a value of 0.29 mg/m^3 of chlorophyll (Table-II).

k) Zoo plankton production was ranged upto 120.71 $mg/100m^3$ dry wt (Table-III).

STATION 6:

a) Temperature of bottom water was colder than surface water, surface water ranged upto the limit of 27°C and bottom water came upto the 19°C.

b) Surface water less saline i.e., 31.24% and bottom water was highly saline than surface water 1.e. 33.25%. Variation in salinity was found to be increased.

c) This station showed a remarkable feature that, both layers have a very low dissolved oxygen content and in a brief limit. Variation in DO at greater depth was inconspicuous.

   DO ranged from 0.84 ml at NTP/L at surface water to 0.50 ml at NTP/L at bottom water.

d) pH varied to a lesser extent. It varied only between 7.50 and 7.75 at surface and bottom water respectively.

e) Suspended load was moderately high i.e., 24.mg/ L.

f) Vertical extinction coefficiency reached upto 0.1000m.

g) A minimum phosphate concentration was observed at surface water i.e., 0.083. µg/L and maximum at bottom water upto 0.122 µg/L. This station showed slightly increase in concent ration at bottom water than previous station 5.

h) Nitrate concentration for both layers showed light higher concentration than previous station 5. Nitrate content was in the range of 0.428 µg/ L at surface water and 0.200µg/L at bottom water. These values showed slight reverse trend.

i) Sarface nitrite concentration was low upto 0.100 µg/L but bottom water nitrite concentration was exceeded upto 1.043 µg/L. This is also a remarkable feature of this station.

j) Planktonic primary production was slightly in a high amount .i.e., 0.42 mg/m^3 (Table-II).

k) Planktonic secondary production was in a less quantity 1.e., 191.89 mg/100m^3 dry wt (Table-III).

STATION 7:

a) Temperature varied to a greater extent. Here it showed existence of low temperature. Bottom water was very cold upto 12°C. This was the lowest temperature amongst at all stations. Surface water showed temperature of 28°C.

b) Salinity difference observed was slight high. Salinity minimum at surface water was 31.08% and salinity maximum at bottom water was 32.75%.

c) Both layers showed a slight variation in DO but comparatively less dissolved oxygen content. At surface water it was 1.01 ml at NTP/L and at bottom water it was 2.03 ml at NTP/L. Bottom water showed comparatively high DO content then surface water.

d) pH varied to a lesser extent. At surface water and bottom water it varied from 7.75 8.00. Bottom water showed slight high pH than surface water.

e) Suspended load was in a amount of 21.7 mg/L.

f) At such greater depth, variation in phosphate concent ration was in-conspicuous i.e., at surface water, maximum concentration upto 0.100 ug/L and at bottom water minimum concentration upto 0.094 µg/L.

g) Nitrate concentration was slightly varied. At surface water it was in less concentration of 0.414 µg/L and at bottom water it was in slight high concentration of 0.743 µg/L.
h) Nitrite concentration was doubled at bottom water than surface water upto 1.328 µg/L and at surface water, the concentration was 0.543µg/L.
i) Planktonic primary production was in a average value of 0.35 mg/m^3 of chlorophyll (Table-II).
j) Planktonic secondary production was slightly higher than 3 average value i.e., 761.37 mg/100 m^3 dry wt (Table-III).

STATION 8:

a) Temperature was ranging from 26°c to 28°c at surface and bottom water respectively.
b) Surface and bottom water salinity being 31.33% 0 and 32.92% respectively. Bottom water have higher salinity than surface water.
c) At this station, bottom water DO content was very low. The content was 0.67 ml at NTP/L at bottom water and at surface water it was 4.74 ml at NTP/L. Variation in DO content was drastic.
d) Slight reverse trend of pH was observed here. Surface water showed 8.50 pH value and bottom water showed 8.00 pH value.
e) Suspended load was comparatively very less. It constituted of 19.1 mg/L.
f) Phosphate concentration at surface and bottom water was very less as compare to other stations. Variation in the phosphate concentration was inconspicuous i.e., surface water showed concentration of 0.050 ug/L and bottom water showed concentration of 0.061 ug/L. Bottom water showed minute excess in content than surface water.
g) This station showed a very great feature. At surface water nitrate concentration was totally absent, and at bottom water, the concentration was 0.128 µg/L.
h) Variation in nitrite concentration was comparatively high. Surface water have less nitrite concentration of 0.071µg/L and bottom water have comparatively high concentration of 0.271 ug/L.
i) Planktonic primary production i.e., chlorophyll value 3 showed comparatively less abundancy i.e., 0.33 mg/m3 (Table-II).
j) Planktonic secondary production was also comparatively very less i.e., 309.50 mg/100 m^3 dry wt (Table-III).

STATION 9:

a) Temperatures are found to be quite similar. Surface water ranging slight high temperature i.e., 28.5°C and bottom water of slight low temperature i.e. 28°C.
b) Salinity varied to a lesser extent but in a reverse trend. Salinity varied only between 32.08% and 3192% at surface and bottom water respectively.
c) Dissolved oxygen content was very low but there was no much difference in DO content. Surface water ranging from 1.35 ml at NTP/L and bottom water was ranging from 0.84 ml at NTP/L.
d) At both layers, slight difference was observed in pH. pH at surface water reached upto 7.75 and bottom water was lowered upto 7.50.
e) Suspended load value was comparatively high i.e. 25.6 mg/L.
f) V.E.C., comparatively it was high i.e., 0.1889 m.
g) Phosphate concentration was quite similar. Concentration was in a brief limit i.e., at surface water it reached upto 0.500 µg/L and at bottom water, it was lowered upto 0.444 ug/L.
h) Nitrate (NO3) concentration at this station was very low at both layers. Surface water have 0.028 ug/L of concent ration and bottom water have 0.057 ug/L of nitrate concentration.
i) This station was also having a very less concentration of nitrite (NO_2). Nitrite concentration was only in the range of 0.085 ug/L to 0.100 ug/L at surface and bottom water respectively.
j) Chlorophyll value was only 0.30 mg/L (Table-II).
k) Planktonic secondary production was very less could not find at any other station. It ranged only upto 99.04 mg/100 m^3 dry wt (Table-II).

STATION 10:

a) Surface water temperature was slightly warmer than bottom water. It was 29.5°C and bottom water was having temperature of 28°C.
b) At surface water, salinity was dominating upto 31.33% and at bottom water, it was lowering upto 30.90%.
c) High dissolved oxygen content at surface water was 5.25 ml at NTP/L and low dissolved oxygen content at bottom water was 4.91 ml at NTP/L. DO content was increased too much than previous station 9.

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d) pH values were slightly co-related. Surface water showed higher value of 7.75 and bottom water showed lower value of 7.50.

e) Suspended load was in a loan amount 1.0., 16.7 mg/L.

f) Water was less turbid. V.B.C. was 0.1700 m. But slightly turbidity was observed than previous atation 9.

g) Phosphate concentration at both layers was in less quantity than previous station 9. Concentration was lowered at surface wator upto 0.072 µg/L and it increased at bottom only upto 0.105 µg/L.

h) With comparing of previous station and this station, nitrate (No) concentration values were slightly correlated. But only the main feature is that, both layer are showing same nitrate content i.e., 0.057 µg/L.

i) Nitrite (NO_2) concentration was slightly increased than previous station. Surface water have low nitrite content upto 0.100 µg/L and bottom water have slight higher nitrite content upto 0.144 µg/L.

j) Planktonic primary production was slightly enriched upto 0.42 mg/m^3 of chlorophyll (Table-II).

k) Planktonic secondary production was very low reached value of 129.99 mg/100m^3 dry wt (Table-III).

STATION 11:

a) Both layers showed same temperature i.c., 28.5^{0}C.

b) Both layers have quite similar water salinity. Surface water have more salinity i.e., 31.33% and bottom water have slight low salinity 1.0. 31.08%.

c) This station showed very less oxygenated water at both surfaces. At surface water, DO content reached upto 0.84 ml at NTP/L and at bottom water it lowered upto 0.50 ml at NTP/L.

d) Both layers have not showed any variation in pH. The value was 7.75.

e) Suspended load was comparatively less upto 15.6 mg/L.

f) V.E.C. was slightly high i.e., 0.1545 m. But the water was slightly more turbid than previous station 10.

g) Phosphate concentration was moderately in a range. Surface water showed slight high concentration upto 0.155 µg/L and bottom water showed low concentration upto 0.111 µg/L.

h) Nitrate concentration was comparatively low. Variation in concentration was 0.114 µg/L and 0.171 µg/L at surface and bottom water respectively.

i) Planktonte primary production was comparatively high, showed value of 0.45 mg/m^3 of chlorophyll (Table-IX).

j) Planktonte secondary production was also moderately high reached upto 779.94 mg/100 m^3 dry wt (Table-III).

STATION 12:

a) Generally subsurface water temperature was always lower than the corresponding temperatures of the surface water. But here, values showed reverse trend. Surface water temperature was having temperature of 30°C and bottom water of 29°C. Both layers have comparatively high tomperature values.

b) Salinity was ranging high. At surface water, salinity was more 1.0., 32.25% and at bottom water, salinity was comparatively less 1.0., 32.07%.

c) The station was well oxygenated showing higher DO content. DO variation at surface and bottom was 6.26 ml at NTP/L and 5,75 ml at NTP/L.

d) pH was decreased as compared to the previous station 11. Both layers showed pH of 7.50.

e) Suspended load value was comparatively low 1.e., 17.3 mg/L.

f) Phosphate concentration varied to a comparatively lesser extent. Phosphate content was dominating at bottom water upto 0.161 µg/L and lowering at surface water upto 0.050 µg/L.

g) Nitrate values were slightly increased as compare to the Nitrate concentration was within the range of 0.157 µg/L and 0.300 µg/L at surface and bottom water respectively. Bottom water doubled in its concentration than surface water.

h) Nitrite content was minimum at surface water was showing concentration of 0.328 µg/L and maximum at bottom water was showing concentration of 0.471 µg/L.

i) This station showed a peculiar feature. Planktonic primary production was very less upto 0.29 mg/m^3 of chlorophyll (Table-II).

j) Planktonic secondary production was reaching its peak 3 of 2165.50 mg/100 m^3 dry wt (Tablo - III).

STATION 13:

a) Surface water temperature increased upto 29°c and bottom water temperature was lowered upto 26°C.

b) Surface water salinity was lowered upto 31.33% but bottom water was highly saline up to 34.18%. This station showed a great variation at surface water and bottom water salinity.

c) DO content was more. Surface water DO content increased upto 5.41 ml at NTP/L. Bottom water showed increase in dissolved oxygen content upto 4.23 ml at NTP/L.

d) pH value exceeds upto 7.50 and 7.75 at surface and bottom water respectively.

e) Suspended load was slightly enriched opte 21.1 mg/L.

f) The concentration of phosphate ranged between minimum upte 0.172 μg/L and maximum upto 0.411 μg/L. Bottom water was increased in its concentration.

g) Nitrate (NO_3) at this station showed alight fall in the concentration. Minimum content was 0.128 μg/L occuring at surface water and maximum content was 0.142 μg/L occuring at bottom water.

h) Nitrite (NO_2) values also showed slight fall in the concentration. Reverse trend was observed here. Surface water showed high concentration upto 0.214 μg/L and bottom water showed less concentration upto 0.157 μg/L.

i) Planktonic primary production was exceeded upto 0.35 mg/ m^3 (Table-II).

j) Planktonic secondary production showed enrichment upto 2042.70 mg/100 m^3 dry wt (Table-III).

STATION 14:

a) Higher temperature was observed upto 29°C at surface water and lower temperature was observed only 18°C at bottom water. The temperature showed vide variation.

b) Surface water was less saline upto 30.99% and bottom water was highly saline showing salinity of 33.51%. This station also showed wide salinity variation.

c) Dissolved oxygen content was higher at surface water reaching upto 4.91 ml at NTP/L and it was lowered too much at bottom water upto 0.84 ml at NTP/L. This station was showing varying amount of DO content at both layers.

d) pH was decreasing as increasing in depth. At surface water, it was increased upto the value of 7.75 and lowered at bottom water upto the value of 7.50.

e) Suspended load was dominating, showing the amount of 28.0 mg/L.

f) Phosphate concentration was lowered of 0.061 μg/L at surface water and showed highest phosphate content of 0.667 μg/L at bottom water. This station showed much variation of phosphate concentration at surface and bottom water.

g) Special feature was observed at this station. With compare to previous station 13, the surface nitráto and bottom nitrate showed same values. Surface water was showing minimum nitrate concentration up to 0.128 μg/L and bottom water was showing maximum nitrate concentration upto 0.142 μg/L.

h) For nitrite also, this station showed a special feature. Values were same as compare to the previous station. Surface water was reaching slightly high nitrite concent ration upto 0.214 μg/L and bottom water was lowering concentration upto 0.157 μg/L.

i) Planktonic primary production was moderately high dominating upto 0.43 mg/m^3 of chlorophyll (Table-II).

j) Planktonic secondary production was very low upto 371.40 mg/100 m^3 dry wt (Table-III).

STATION 15:

a) Temperature at surface water was reaching highest upto 30°C and temperature at bottom water was slightly decreased upto 28°C.

b) Salinity was comparatively higher. Surface water was having low salinity upto 32.08% and bottom water salinity enhanced upto 32.92%.

c) Water was highly oxygenated. 5.41 ml at NTP/L content of dissolved oxygen was observed at surface water. It was in a considerable amount but slightly lowered upto 4.74 ml at NTP/L at bottom water.

d) At surface water, pH was highly increased showing the value of 8.50 and bottom water was lowered up to 7.50. Variation in pH was rather high.

e) Deficiency upto 15.8 mg/L of suspended load was noticed.

f) Water was slightly clear, showing V.E.C. of 0.1700 m.

g) Phosphate concentration was declined completely at surface water upto 0.044 μg/L and slightly increased at bottom wator only upto 0.100 μg/L.

h) The concentration of nitrate ranged between maximum of 0.314 μg/L and minimum of 0.128 μg/L at surface and bottom water respectively. Surface water showed slight more concentration than the bottom water.

i) Nitrite concentration was slightly increased. At bottom layers it was found to be 0.300 μg/L and at surface layer it was found to be 0.328 μg/L.

j) Planktonic primary production was lowered slightly upto 3 0.32 mg/m^3 of chlorophyll (Table-II).

k) Planktonic secondary production was also declined 3 very much upto 309.50 $mg/100m^3$ dry wt (Table-III).

STATION 16:

a) Temperature at surface, exceeded maximum upto 30°C. At bottom water, the temperature was lowered only upto 25°C. Bottom water was warmer.

b) Salinity was lowered at this station. Maximum saline water was occuring at surface water, showing 31.08%. Minimum saline water was occuring at bottom water, showing 30.90%. Bottom water salinity was decreased at this station.

c) Sudden fall of DO was observed. Slight rise upto 1.18 ml at NTP/L, DO content was found at surface water and lowered DO content of 0.84 ml at NTP/L was found at bottom water. The values were generally low.

d) pH was quite similar, 7.75 value at surface and bottom water.

e) Suspended load concentration was increased only upto 21.9 mg/L.

f) V.E.C. was 0.1700 m showing a slight turbid water.

g) Phosphate concentration was in a trace amount. The content of phosphate ranged only between 0.050 μg/L and 0.038 μg/L at surface and bottom water respectively. The concentration was generally very low.

h) The nitrate (NO_3) concentration was increased suddenly. It remained lower upto 0.514 μg/L at surface water and higher upto 0.914 μg/L at bottom water. Bottom water showed high concentration of nitrate.

i) This station showed a great varying feature of surface and bottom nitrite concentration. Surface water nitrite concentration increased upto 0.885 μg/L. Bottom water nitrite content increased upto 1,257 μg/L. Bottom water was having higher nitrite content.

j) Planktonic primary production was dominated upto $0.40mg/m^3$ of chlorophyll (Table-II).

k) Planktonic secondary production was slightly increased 3 upto 389.97 $mg/100\ m^3$ dry wt (Table-III).

STATION 17:

a) Surface water and bottom water was exceeding upto 29°C temperature.

b) Salinity was comparatively high ranged between 32.58% and 31.75% at surface and bottom water respectively. Surface water was more saline than bottom water.

c) Surface water showed very low DO content, could not find at any station for surface water. It was 0.67 ml at NTP/L. Bottom water also showed less oxygen value upto 0.84ml at NTP/L. At both layers, DO content remained moderately low. The variation at both layers was inconspicuous.

d) pH higher and lower values being 7.50 and 7.75 at surface and bottom water respectively.

e) Suspended load concentration was 20.1 mg/L.

f) Water was very clear, showing VEC. of 0.1889m.

g) A minimum concentration of phosphate was observed at surface water upto 0.044 μg/L and maximum upto 0.133 μg/L, at bottom water. Phosphate at surface water was in a trace amount.

h) Nitrate (NO_3) content was slightly co-related at both layers. Surface water nitrite concentration was low showing the value of 0.085 μg/L and bottom water nitrite concentration was slightly more showing the value of 0.100 μg/L. This station was having deficiency in phosphate concentration.

i) Nitrite (NO_2) content was decreased upto 0.128 μg/L and 0.185 μg/L at surface and bottom water respectively. Bottom water was having comparatively high nitrite concentration.

j) Planktonic primary production was moderately high reaching chlorophyll content upto 0.40 mg/m^3 (Table-II).

k) Planktonic secondary production was increased suddenly 3 and reached upto 674.71 mg/100 m^3 dry wt (Table-III).

STATION 18:

a) Temperature showed a reverse strend. Bottom water have higher temperature of 30°C and surface water have lower temperature of 29°C.

b) Salinity was varied to a lesser extent. It varied between 32.33% and 32.58% minimum at surface and maximum at bottom water respectively.

c) Dissolved oxygen content was slightly increased than previous station 17. DO content at surface water and bottom water was in a brief limit between 2.37 and 1.35 ml at NTP/L respectively. Slight more DO content was observed at surface water.

d) pH ranged from 7.75 to 7.50 at surface and bottom water respectively.

e) Suspended load value was moderately increased upto 21.3mg/L.

f) Phosphate concentration at surface water was moderately less showing the value of 0.77 µg/L and at bottom water it was increased upto 0.105 µg/L.

g) Nitrate content at surface water was in a trace amount and at bottom water concentration increased upto 0.157 µg/L.

h) Nitrite concentration was enhanced at both layers, 0.214 µg/L minimum at surface water and 0.357 g/L maximum at bottom water.

i) Planktonic primary production declined upto 0.35 mg/m^3 of chlorophyll content (Table II).

j) Planktonic secondary production was enriched upto 1238.00 mg/100 m^3 dry wt (Table-III).

STATION 19:

a) Temperature variation was high. At surface water it was 26°C and at bottom water it was only 20.1°C. Surface water was slightly warmer.

b) Bottom water was highly salim, the value of 35.85% was could not observed at any station. Surface water was also highly salihe upto 32.07%. Salinity variation was high.

c) Surface water highly oxygenated showed DO content of 5.08 ml at NTP/L and bottom water showed very much deficiency of DO content i.e., 0.84 ml at NTP/L.

d) Generally pH decreases with increasing in depth but reverse trend was observed here. That means, surface water pH was less i.e., 7.50 and bottom water pH was increased up to 8.00.

e) 20.8 mg/L of suspended value was observed. It was slightly increased with compare to the previous station 18.

f) Same as previous station, phosphate content was 0.077µg/L at surface water and 0.061 µg/L at bottom water.

g) Again nitrate concentration showed a slight rise. 0.185 µg/L of less concentration was observed at surface water and 0.285 µg/L concentration was observed at bottom water.

h) Nitrite content of surface water was samo with compare to the previous station i.e., 0.214 µg/L. But concentration of nitrite at bottom water suddenly reached up to 0.971µg/L.

i) Planktonic primary production was moderately high i.e. 0.37 mg/m m^3 of chlorophyll (Table-II).

j) Planktonic secondary production was enhanced up to 1052.30 mg/100 m^3 dry wt (Table-III).

STATION 20:

a) Higher temperature was observed upto 28^0C at surface water and the temperature was lowered only upto 26^0C at bottom water. Bottom wator was having warmer water.
b) Balinity was varied to a greator extent. 31.33% malino Water was observed at surface water and higher saline wator upto 34.01% was observed at bottom water. Balinity showed a wide variation.
c) Dissolved oxygen was fairly high. At surface water, DO content reached upto 5.08 ml at NTP/L and at bottom water, DO content reached upto 6.26 ml at NTP/L.
d) Variation in pH was rather high. PH at surface water was 7.50 and increased at bottom water upto 8.25.
e) Suspended load content was enhanced upto 22.2 mg/L. It was increased with compare to previous station 19.
f) Phosphate content at surface water was moderately high, reached upto 0.144 μg/L and at bottom water, the concentration was very much decreased upto the level of 0.044 μg/L.
g) Nitrate concentration was declined. Content was lowered upto 0.142 μg/L at surface water and slight increased upto 0.171 μg/L at bottom water. Nitrate concentration was slightly correlated at surface and bottom water.
h) Special feature of nitrite content was observed at this station, that nitrite concentration for both layers reached as a same value upto 0.257 μg/L.
i) Planktonic primary production was enhanced upto 0.41 mg/m^3 of chlorophyll (Table-II).
j) Planktonic secondary production was showed deficient value 3 of 241.41 mg/100 m^3 dry wt (Table-III).

STATION 21:

a) Temperature range was in a brief limit. At surface water, it showed the value of 28°C and at bottom water, it increased upto 28.4°C (Table-I-A). Bottom water was warmer.

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b) Salinity varied between 31.92% and 32.50% at surface water and bottom water respectively (Table-I-A). Bottom water was highly salino than surface water.

c) Very low DO content was observed. 1.18 ml at NTP/L at surface water and 0.67 ml at NTP/L very less DO content at bottom water respectively. Sudden decline was observed (Table-I-B). Dissolved oxygen value was lowered too much with compare to the previous station 21.

d) (d) Variation in pH was high, 7.50 pH at surface water and 8.25 pH at bottom water (Table-I-B).

e) Suspended load was again decreased upto 18.0 mg/L. It was observed in very less concentration (Table-I-B).

f) Maximum phosphate concentration was observed at surface water and minimum at bottom water. 0.177 μg/L concentration was observed at surface water, 0.066 μg/L at bottom water (Table-I-C).

g) Nitrate (NO_3) content was lowered upto 0.085 μg/L at surface water and slightly increased upto 0.114 μg/L at bottom water respectively (Table-I-C). Nitrate content was lowered at this station.

h) Nitrite concentration was increased. Lower and higher values being 0.257 μg/L and 0.371 μg/L at surface and bottom water respectively (Table-I-C).

i) Planktonic primary production showed deficiency upto 0.32 mg/m^3 (Table-II).

j) Planktonic secondary production raised upto 489.00 $mg/100m^3$ dry wt (Table-III).

STATION 22:

a) Temperature ranged from 27.8°C to 22.6°C at surface and bottom water respectively. The variation in temperature was comparatively high. Bottom water showed comparatively loss temperature than surface water.

b) Typical saline water was observed. Salinity varied only between 31.83% and 32.92%; minimum at surface water and maximum at bottom water respectively.

c) DO content was very low. Oxygen minimum upto 1.69 ml at NTP/L was observed at surface water and oxygen maximum upto 2.03 ml at NTP/L was observed at bottom water. Bottom water DO content was slightly increased.

d) For pH, reverse trend was observed. Surface water showed high pH value upto 8.00 and bottom water upto 7.50. Variation in pH was rather high.

e) Suspended load exhibited a remarkable fall of 12.6 mg/L. This concentration was very low as compare to other stations.

f) Slightly turbid water was observed. V.E.C. value was 0.1545 m.

g) Variation in phosphate concentration was negligible. At surface water, the concentration was 0.105 µg/L and at bottom water, the concentration was 0.100 µg/L. Bottom water phosphate content was slightly increased.

h) Nitrate (NO_3) concentration at surface water was exceeding upto 0.100 µg/L but at bottom water nitrate concentration was suddenly decreased upto the level of 0.085/µg/L.

i) Nitrite (NO_2) content was decreased upto the level of 0.185 µg/L and 0.114 µg/L at surface and bottom water respectively. Bottom water was having low nitrite content with compare to the surface water nitrite content.

j) Planktonic primary production was in excess amount showed value of 0.45 mg/m^3 of chlorophyll (Table-II).

k) Considerable fall of planktonic secondary production 3 value was observed only upto 216.66 mg/100 m^3 dry wt (Table-III).

STATION 23:

a) Temperature varied between 28°c and 27°c at surface and bottom water respectively. Water found to be warmer.

b) Typical saline water was observed. Minimum salinity at surface water was 31.66% and maximum at bottom water was 32.08%.

c) Dissolved oxygen was in lower content. At surface water, it was showing the DO content of 1.52 ml at NTP/L. At bottom water, it was very less of 0.84 ml at NTP/L. Surface water showed slight high DO content.

d) At surface water and bottom water, the pH was ranging from 7.75 to 7.50. Surface water was having high pH value.

e) Suspended load concentration was only 16.1 mg/L. It was comparatively in less amount.

f) Variation in phosphate content was inconspicuous. At surface water, it was 0.155 ug/L and at bottom water it was 0.150 ug/L.

g) The peak content of planktonic primary production was 3 observed. The content was 0.60 mg/m^3 of chlorophyll (Table-II).

h) Planktonic secondary production was comparatively very upto 272.36 mg/100 m^3 dry wt (Table-III).

STATION 24:

a) Reverse trend of temperature was observed. Low temperature of 27.2°C was observed at surface water and higher temperature of 28.3°C was observed at bottom water.

b) Salinity value increased and varied between 32.17% and 33.00% at surface and bottom water respectively. Surface water was showing low salinity than bottom water.

c) DO content was decreased again at surface water upto 1.35 ml at NTP/L and the content was increased at bottom upto the level of 0.87 ml at NTP/L. Surface water showed slight high DO content as compared to the bottom water.

d) pH was decreased. At surface and bottom water the pH was same i.e., 7.50.

e) Highly increased suspended load concentration was observed upto 25.8 mg/L. Suspended load was abundant.

f) Very poor phosphate content was observed. Variation was in a lesser extent. Minimum phosphate content at surface water was 0.044 µg/L and minimum phosphate content at bottom water was 0.055 µg/L.

g) Nitrate concentration of 0.085 ug/L was very poor at surface water. Concentration at bottom water was enhanced upto 0.200 µg/L.

h) Comparatively low nitrite content was observed. Low nitrite concentration at surface water observed, was 0.328 µg/L and high nitrite concentration at bottom water observed, was 0.471 µg/L.

i) Planktonic primary productivity was comparatively high, showing the value of 0.44 mg/L (Table-II).

j) Planktonic secondary productivity was suddenly increased upto the level of 1733.00 mg/100 m^3 dry wt (Table-III).

STATION 25:

a) Temperature was ranging from 28°C to 26°C at surface and bottom water respectively. Bottom water was having less temperature than surface water. Both layers were comparatively warmer (Table-I-A).

b) Amongst the surface water salinity at different stations, this station was having more saline water of 33.84%. Bottom water salinity was also increased upto 34.26%. More saline water was encountered at both layers (Table-I-A).

c) Drastic change in DO content was observed with compare to the previous four stations. Both layers were highly oxygenated. Dissolved oxygen was minimum upto 5.08 ml at NTP/L at surface water and maximum upto 5.92 ml at NTP/L at bottom water (Table-I-B).

d) pH at surface and bottom water was stable 1.0. 8.00. pH remained high (Table-I-B).

e) Suspended load content was again reduced upto the level of 16.8 mg/L (Table-IB).

f) Phosphate content was comparatively low. Phosphate content was low at surface water and high at bottom water, was found to vary between 0.083 μg/L and 0.105 μg/L respectively (Table-I-C).

g) Very much deficiency of nitrate content was observed. At surface water and bottom water the nitrite concentration was stable, showing the concentration of 0.042 μg/L (Table-I-C).

h) At surface and bottom water, lower and higher values of nitrite being 0.114 μg/L and 0.157 μg/L respectively. The concentration was varied to a lesser extent. But comparatively more content of nitrite was encountered at bottom water (Table-I-C).

i) Planktonic primary production was in a considerable amount increased upto 0.40 mg/L (Table-II).

j) Planktonic secondary production was quite low, decreased up to the level of 309.50 mg/100 m^3 dry wt (Table-III).

Table I-A: Hydrographic parameters in surface and bottom waters off Karnataka Coast

Station No.	Sampling depth (Mtrs)	Temperature ^{0}C		Salinity %	
		SW	BW	SW	BW
1	25	28	26	31.22	31.22
2	25	28	25.7	31.41	31.66
3A	36	26	29	30.40	30.99
3B	25	27	28	30.74	31.41
3C	25	28.5	28.5	30.66	30.74
4	31	26	25.5	31.25	31.50
5	83	29	28	31.58	31.42
6	415	27	19	31.24	33.25
7	1645	28	12	31.08	32.75
8	195	26	28	31.33	32.92
9	58	28.5	28	32.08	31.92
10	25	29.5	28	31.33	30.91
11	32	38.5	28.5	31.33	31.08
12	60	29	30	32.25	32.07
13	102	29	26	31.33	34.18
14	195	29	18	30.99	33.51
15	55	30	28	32.08	32.92
16	18	30	25	31.08	30.99
17	15	29	29	32.58	31.75
18	52	29	30	32.33	32.58
19	60	26	20.1	32.07	35.85
20	110	28	26	31.33	34.01
21	50	28	28.4	31.33	34.01
22	18	27.08	22.6	31.83	32.92
23	5	28	27	31.66	32.08
24	72	27.2	28.3	31.17	33.00
25	190	28	26	33.84	34.26
Mean		28.07	25.87	31.60	32.36

Table I-B: hydrographic parameters in surface and bottom waters off Karnataka Coast

Station No.	D.O. ml at NTP/L		pH		Suspended load mg/L	V.E.C. (Mtrs)
	SW	BW	SW	BW		
1	5.92	4.74	8.75	8.80	---	0.1214
2	6.43	5.25	8.61	8.66	---	---
3A	7.70	7.45	8.68	8.68	---	---
3B	7.79	6.60	8.70	8.94	---	0.0653
3C	6.85	6.52	9.02	8.68	30.0	---
4	5.75	5.58	8.00	7.50	19.7	0.1214
5	4.57	4.40	7.75	7.75	18.0	0.0850
6	0.84	0.50	7.50	7.75	24.00	0.1000
7	1.01	2.03	7.75	8.00	21.7	---
8	4.74	0.67	8.50	8.00	19.1	---
9	1.35	0.84	7.75	7.50	25.6	0.1889
10	5.25	4.91	7.75	7.50	25.6	0.1889
11	0.84	0.50	7.75	7.50	16.7	0.1700
12	6.26	5.75	7.50	7.50	17.3	---
13	5.41	4.23	7.50	7.75	21.1	---
14	4.91	0.84	7.75	7.50	28.0	---
15	5.41	4.74	8.50	7.50	15.8	0.1700
16	1.18	0.84	7.75	7.75	21.9	0.1700
17	0.67	0.84	7.50	7.75	20.1	0.1889
18	2.37	1.35	7.75	7.50	21.3	---
19	5.08	0.84	7.50	8.00	20.8	---
20	5.08	6.26	7.75	8.25	22.2	---
21	1.18	0.67	7.50	8.25	18.0	---
22	1.69	2.03	8.00	7.50	12.6	0.1545
23	1.52	0.84	7.75	7.50	16.1	---
24	1.35	0.67	7.50	7.50	25.8	---
25	5.08	5.92	8.00	8.00	16.8	---
Mean	3.47	3.17	7.95	7.92	20.3	0.1408

Table I-C: Hydrographic parameters in surface and bottom waters off Karnataka Coast

Station No.	D.O. Ml at NTP/L		pH		Suspended load mg/L	V.E.C. (Mtrs)
	SW	BW	SW	DW	SW	BW
1	0.261	0.165	5.050	10.846	---	---
2	0.172	0.200	0.900	1.814	1.600	3.815
3A	0.150	0.133	0.814	0.657	1.171	1.057
3B	0.094	0.083	0.157	1.571	0.543	1.357
3C	0.072	0.100	0.271	0.271	0.342	0.171
4	0.127	0.016	0.571	0.543	0.628	0.061
5	0.088	0.011	0.114	0.171	0.142	0.285
6	0.083	0.122	0.428	0.200	0.100	1.043
7	0.100	0.094	0.414	0.743	0.543	1.328
8	0.050	0.061	0.000	0.128	0.071	0.271
9	0.500	0.444	0.028	0.057	0.085	0.100
10	0.072	0.105	0.057	0.057	0.100	0.114
11	0.155	0.111	0.114	0.171	0.157	0.271
12	0.050	0.161	0.157	0.300	0.328	0.471
13	0.172	0.411	0.128	0.142	0.214	0.157
14	0.061	0.667	0.128	0.142	0.214	0.157
15	0.044	0.100	0.314	0.128	0.328	0.300
16	0.050	0.038	0.514	0.914	0.885	0.257
17	0.044	0.133	0.085	0.100	0.128	0.185
18	0.077	0.105	0.057	0.157	0.214	0.357
19	0.077	0.061	0.185	0.285	0.214	0.971
20	0.144	0.044	0.142	0.171	0.257	0.257
21	0.177	0.066	0.085	0.114	0.257	0.371
22	0.105	0.100	0.100	0.085	0.185	0.114
23	0.155	0.150	--	--	--	--
24	0.044	0.055	0.085	0.200	0.328	0.471
25	0.083	0.105	0.042	0.042	0.114	0.157
Mean	0.119	0.140	0.842	0.770	0.366	0.604

Table II: Planktonic primary production (Chlorophyll mg/m^3) at stations 1 – 25

Station No.	Chlorophyll (mg/m^3)
1	0.30
2	0.15
3	0.25
4	0.28
5	0.29
6	0.42
7	0.35
8	0.33
9	0.30
10	0.42
11	0.45
12	0.29
13	0.35
14	0.43
15	0.32
16	0.40
17	0.40
18	0.35
19	0.37
20	0.41
21	0.32
22	0.45
23	0.60
24	0.44
25	0.40
Average	0.36

Table III: Planktonic secondary production (mg/100m³ dry wt.) at stations 1 – 25

Station No.	Total zooplankton production (mg/100m³ dry wt.)
1	272.36
2	897.55
3	928.50
4	123.80
5	120.71
6	191.89
7	761.37
8	309.50
9	99.04
10	129.99
11	779.94
12	2166.50
13	2042.70
14	371.40
15	309.50
16	389.97
17	674.71
18	1238.00
19	1052.30
20	241.41
21	489.00
22	216.66
23	272.36
24	1733.00
25	309.50
Average	644.82

Table IV-A: Variation in the water parameters at the inshore stations

Station No.	Depth (Mtrs)	Temp.(^0C)		Salinity (%)		Dissolved Oxygen ml at NTP/L	
		SW	BW	SW	BW	SW	BW
3	36	26	29	30.40	30.99	7.70	7.45
4	31	26	25.5	31.25	31.50	5.75	5.58
10	25	29.5	28	31.33	30.91	5.25	4.91
11	32	28.5	28.5	31.33	31.08	0.84	0.50
16	18	30	25	31.08	30.90	1.18	0.84
17	15	29	29	32.58	31.75	0.67	0.84
22	18	27.8	22.6	31.83	32.92	1.69	2.03
23	5	28	27	31.66	32.08	1.52	0.84
Range in values	5 to 36	26 to 30	22.6 to 29	30.40 to 32.58	30.90 to 32.92	0.67 to 7.70	0.50 to 7.45
Mean	22.5	28.1	26.82	31.43	31.51	3.07	2.87

pH		Suspended load mg/L	V.E.C.(Mtrs)	Phosphate(PO_4) (µg/L)	
SW	BW			SW	BW
8.68	8.68	----	0.1214	0.150	0.133
8.00	7.50	30.0	0.1214	0.127	0.016
7.75	7.50	16.7	0.1700	0.072	0.105
7.75	7.75	15.6	0.1545	0.155	0.111
7.75	7.75	21.9	0.1700	0.050	0.038
7.50	7.75	20.1	0.1889	0.044	0.133
8.00	7.50	12.6	0.1545	0.105	0.100
7.75	7.50	16.1	----	0.155	0.150
7.50 to 8.68	7.50 to 8.86	12.6 to 30.0	0.1214 to 0.1889	0.044 to 0.155	0.016 to 0.150
7.89	7.76	19.0	0.1543	0.107	0.098

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Nitrate (NO_3) at µg/L		**Nitrite (NO_2) at µg/L**		**Primary production (Chlorophyll mg/m^3) Secondary production (mg/100m^3 dry wt.)**	
SW	**BW**	**SW**	**BW**		
0.814	0.657	1.171	1.051	0.25	928.50
0.571	0.543	0.628	0.061	0.28	123.80
0.057	0.057	0.100	0.114	0.42	129.99
0.114	0.171	0.157	0.271	0.45	779.94
0.514	0.914	0.885	1.257	0.40	389.97
0.085	0.100	0.128	0.185	0.40	674.71
0.100	0.085	0.185	0.114	0.45	216.36
---	---	---	---	0.60	271.36
0.057 to 0.814	0.057 to 0.657	0.100 to 1.171	0.051 to 1.051	0.25 to 0.60	123.80 to 928.50
0.322	0.361	0.464	0.436	0.40	415.61

Table IV-B: Variation in the water parameters at the mid-shelf stations

Station No. Depth (Mtrs)		Temp.^{0}C		Salinity (%)		Dissolved oxygen ml at NTP/L	
		SW	BW	SW	BW	SW	BW
2	25	28	25.7	31.41	31.66	6.43	5.25
5	83	29	28	31.58	32.42	4.57	4.40
9	58	28.5	28	32.08	31.92	1.35	0.84
12	60	29	30	32.25	32.07	6.26	5.75
15	55	30	28	32.08	32.92	5.41	4.74
18	65	29	30	32.33	32.58	2.32	1.35
21	50	28	28.4	31.92	32.50	1.18	0.67
24	72	27.2	28.3	32.17	33.00	1.35	0.67
Range in value	25 to 30	27.2 to 30	25.7 to 30	31.41 to 32.25	31.66 to 33.00	1.18 to 6.43	0.67 to 5.75
Mean	58.50	28.50	28.3	31.97	32.38	3.60	2.95

pH		Suspended load (mg/L) V.E.C.(Mtrs)		Phosphate (P0$_4$) (µg/L)	
SW	BW			SW	BW
8.61	8.66	---	--	0.172	0.200
7.75	7.75	18.0	0.0950	0.088	0.011
7.75	7.50	25.6	0.1889	0.500	0.444
7.50	7.50	17.3	---	0.050	0.161
8.50	7.50	15.8	0.1700	0.044	0.100
7.75	7.50	21.3	---	0.077	0.105
7.50	8.25	18.0	----	0.177	0.066
7.50	7.50	25.8	----	0.044	0.055
7.50 to 8.11	7.50 to 8.66	15.8 to 25.8	0.0850 to 1.1889	0.044 to 0.500	0.011 to 0.444
7.85	7.77	20.25	1.1479	0.144	0.155

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Nitrate (NO_3) µg/L		**Nitrate (NO_2) µg/L**		**Primary Production (Chlorophyll mg/m^3) secondary Production mg/100 m^3 dry wt.)**	
SW	**BW**	**SW**	**BW**		
0.900	1.814	1.600	3.815	0.15	897.55
0.114	0.171	0.142	0.285	0.29	120.71
0.028	0.057	0.085	0.100	0.30	99.04
0.157	0.300	0.328	0.471	0.29	2165.50
0.314	0.128	0.328	0.300	0.32	309.50
0.057	0.157	0.214	0.357	0.35	1238.00
0.085	0.114	0.257	0.371	0.32	489.00
0.085	0.200	0.328	0.471	0.44	1733.00
0.028 to 0.900	0.057 to 1.814	0.085 to 1.600	0.100 to 3.815	0.15 to 0.44	99.04 to 1733.00
0.217	0.367	0.410	0.771	0.30	881.53

Table IV-C: Variation in the water parameters at the shelf-edge stations

Station No. Depth (Mtrs)		Temp.(^{0}C)		Salinity (%)		Dissolved oxygen ml at NTP/L	
		SW	BW	SW	BW	SW	BW
1	25	28	26	21.22	31.22	5.92	4.74
6	415	27	19	31.24	33.25	0.84	0.50
7	1645	28	12	31.08	32.75	1.01	2.03
8	195	26	28	31.33	32.92	4.74	0.67
13	102	29	26	31.33	34.18	5.41	4.23
14	195	29	18	30.99	33.51	4.91	0.84
19	60	26	20.1	32.07	35.85	5.08	0.84
20	110	28	26	31.33	34.01	5.08	6.26
25	190	28	26	33.84	34.26	5.08	5.92
Range in Values	25 to 1645	26 to 29	12 to 28	30.99 to 33.84	31.22 to 35.85	1.01 to 5.92	0.67 to 5.92
Mean	326.33	27.75	22.76	31.76	33.64	4.65	3.19

pH		Suspended load (mg/L) V.E.C. (Mtrs.)		Phosphate (PO^4) (ug/L)	
SW	BW			SW	BW
8.75	8.80	---	0.1214	0.261	0.165
7.50	7.75	24.0	0.1000	0.083	0.122
7.75	8.00	21.7	---	0.100	0.094
8.50	8.00	19.1	---	0.050	0.061
7.50	7.75	21.1	---	0.172	0.411
7.75	7.50	28.0	---	0.061	0.667
7.50	8.00	20.8	---	0.077	0.061
7.75	8.25	22.2	---	0.144	0.044
8.00	8.00	16.8	---	0.083	0.105
7.50 to 8.75	7.50 to 8.80	16.80 to 28.0	0.1214 to 28.0	0.061 to 0.261	0.044 to 0.667
7.93	8.03	21.38	0.1214	0.118	0.201

Nitrate (NO_3) µg/L		**Nitrite (NO_2) at µg/L**		**Primary production (chlorophyll mg/m^3)**	**Secondary production (mg/100m^3 dry wt.)**
5.050	10.846	---	---	0.30	272.36
0.428	0.200	0.100	0.043	0.42	191.89
0.414	0.743	0.543	1.328	0.35	761.37
0.000	0.128	0.071	0.271	0.33	309.50
0.128	0.142	0.214	0.157	0.35	2042.70
0.128	0.142	0.214	0.157	0.43	371.40
0.185	0.285	0.214	0.971	0.37	1052.30
0.142	0.171	0.257	0.257	0.41	241.41
0.042	0.042	0.114	0.157	0.40	309.50
0.000 to 5.050	0.042 to 10.846	0.071 to 0.543	0.157 to 1.328	0.30 to 0.43	241.41 to 2042.70
0.761	1.562	0.201	0.471	0.36	670.06

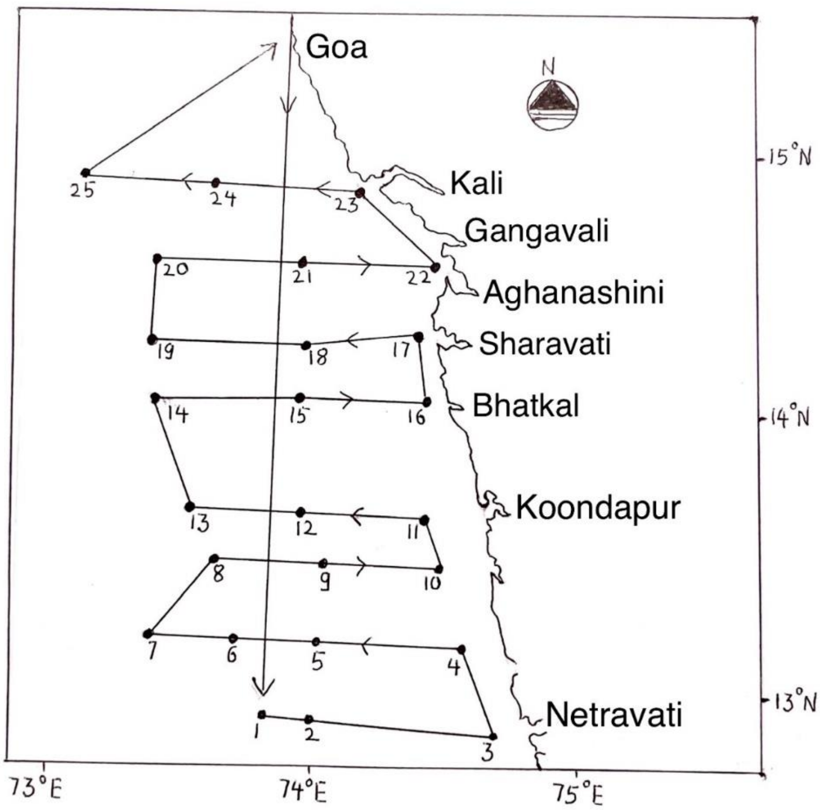

Fig.1A: Cruise track of R. V. Gaveshani cruise No.208

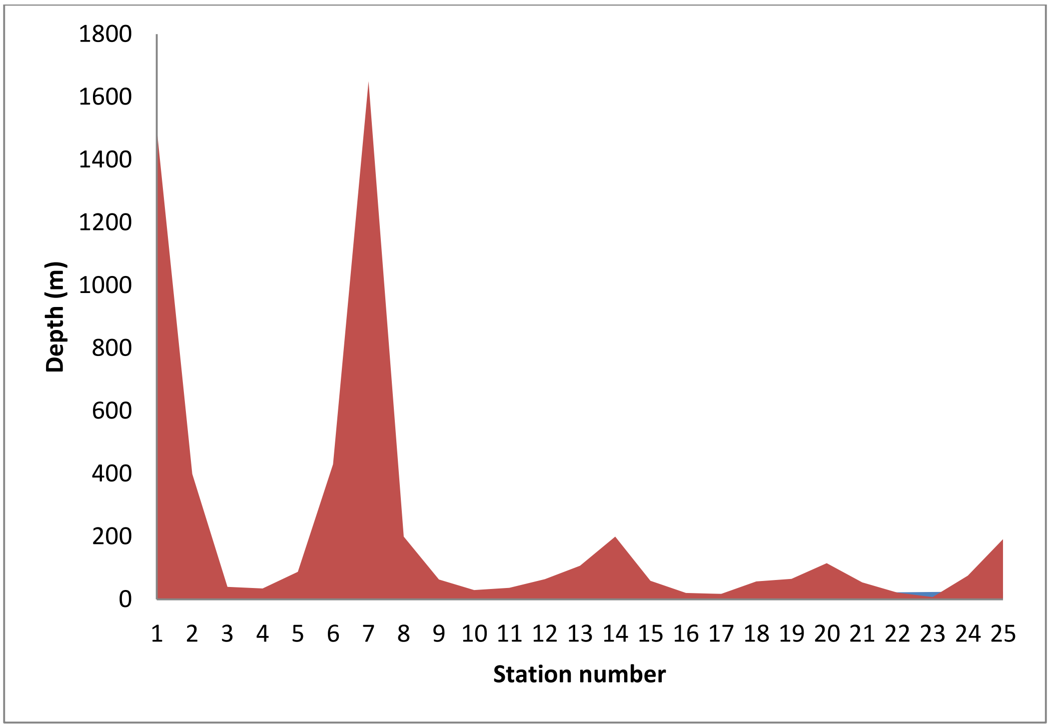

Fig. 1B: Depth distribution amongst the study stations

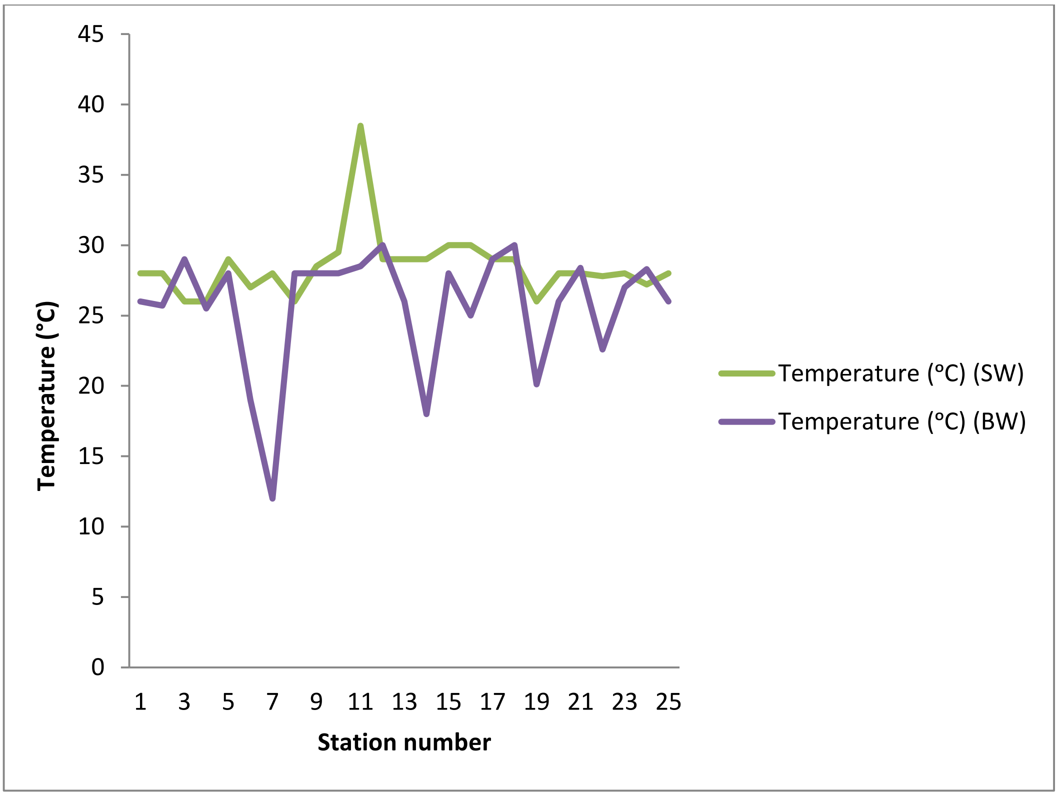

Fig. 2: Distribution of temperature (°C) in the shelf waters of Karnataka

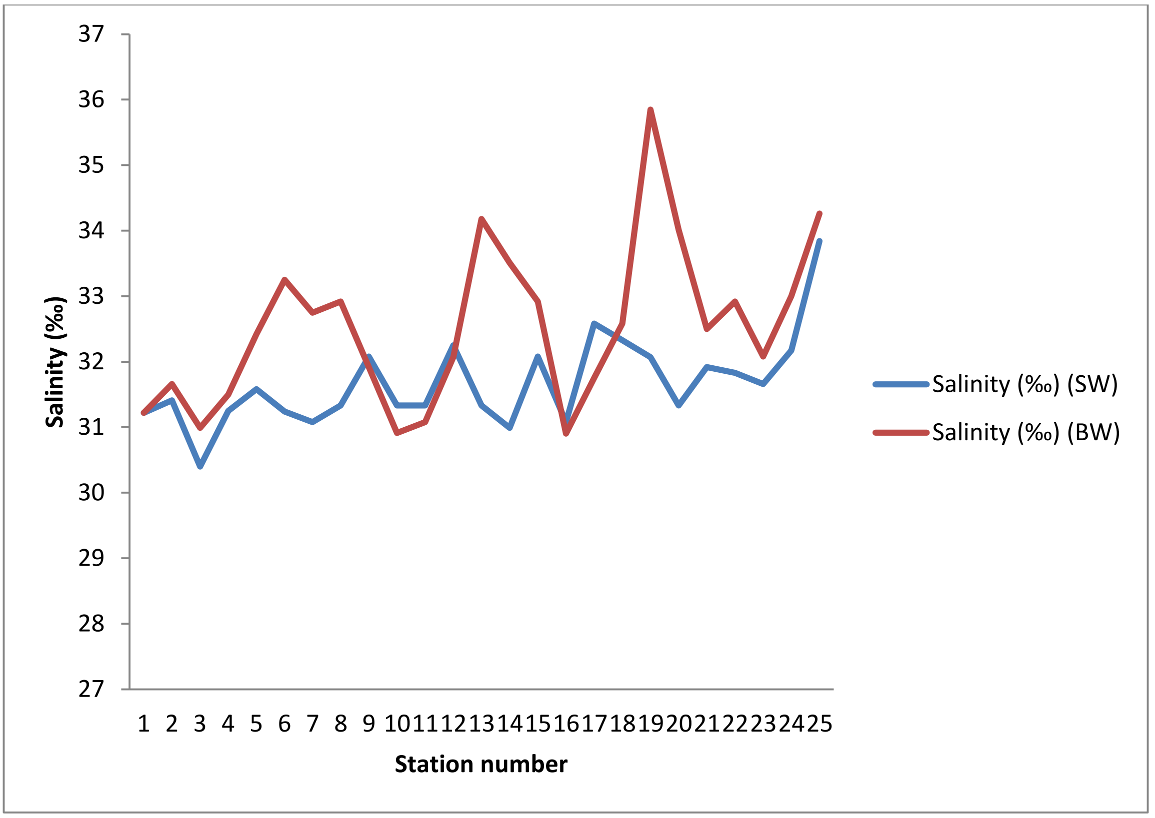

Fig. 3: Distribution of salinity in the shelf waters of Karnataka

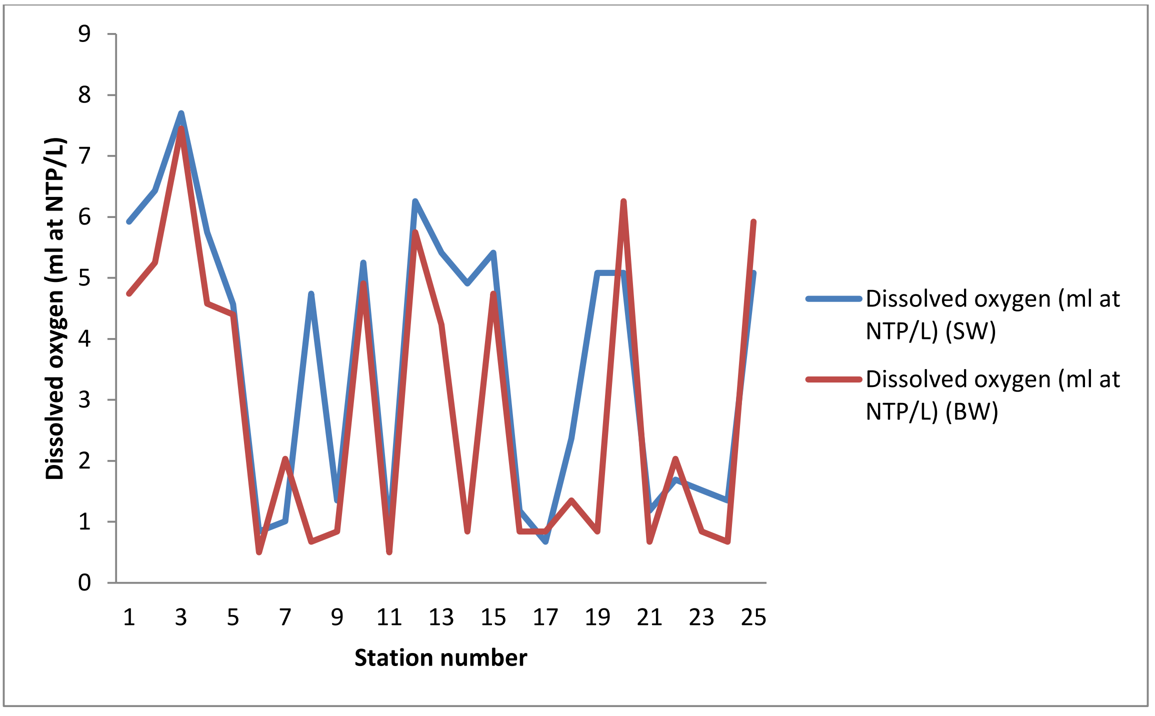

Fig. 4: Distribution of dissolved oxygen in the shelf waters of Karnataka

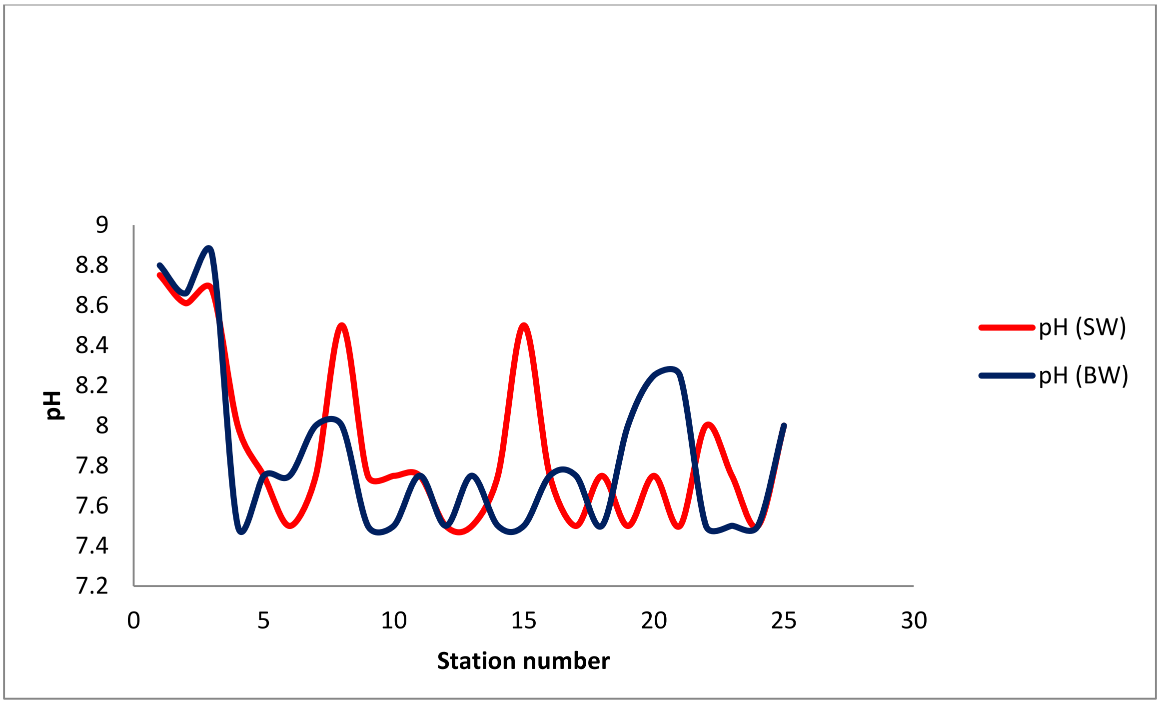

Fig. 5: pH of the surface and bottom waters of the shelf waters off Karnataka Coast

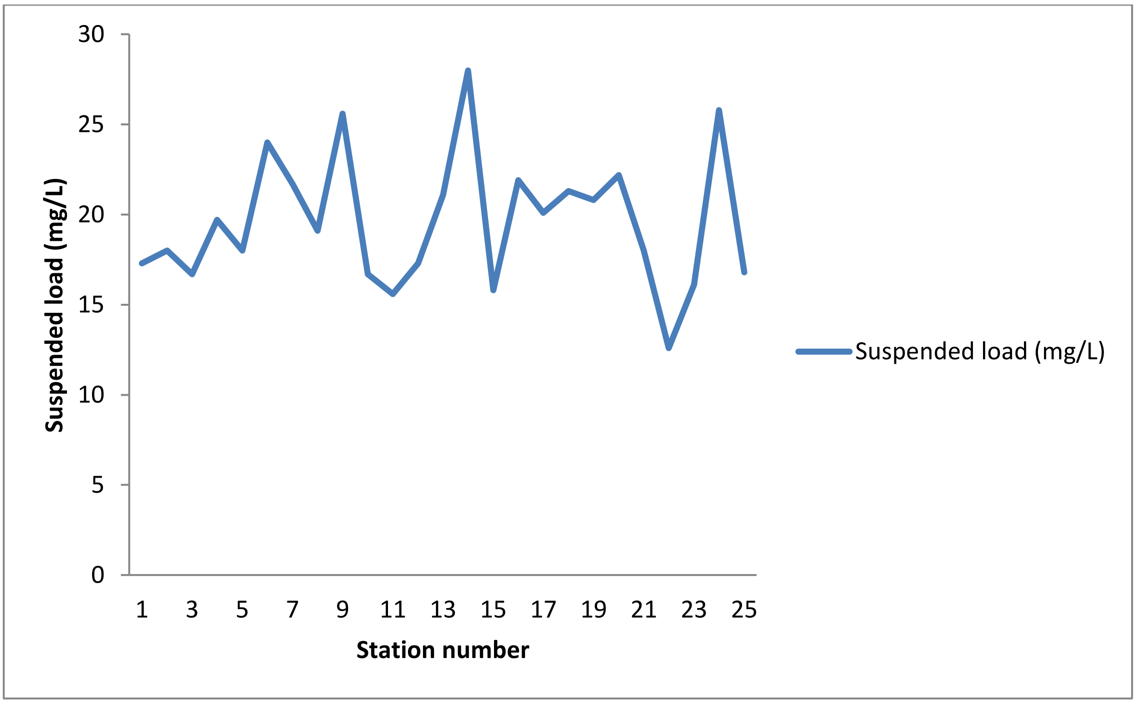

Fig. 6: Distribution of suspended load (mg/L) in the shelf waters of Karnataka

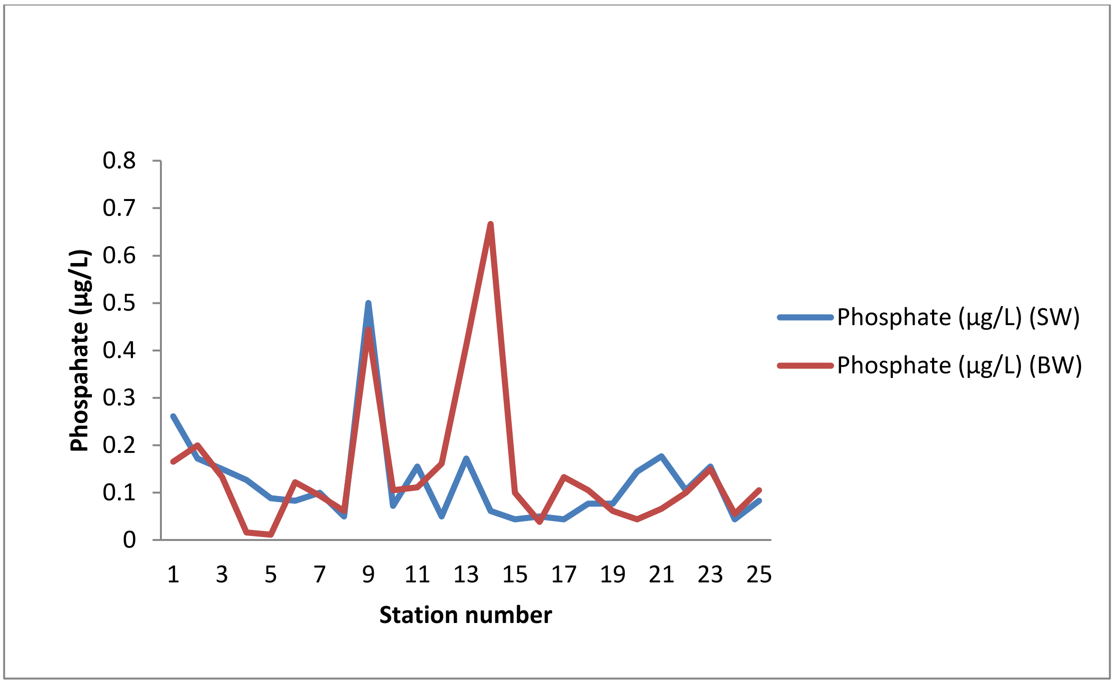

Fig. 7: Distribution of phosphate in the shelf waters off Karnataka Coast

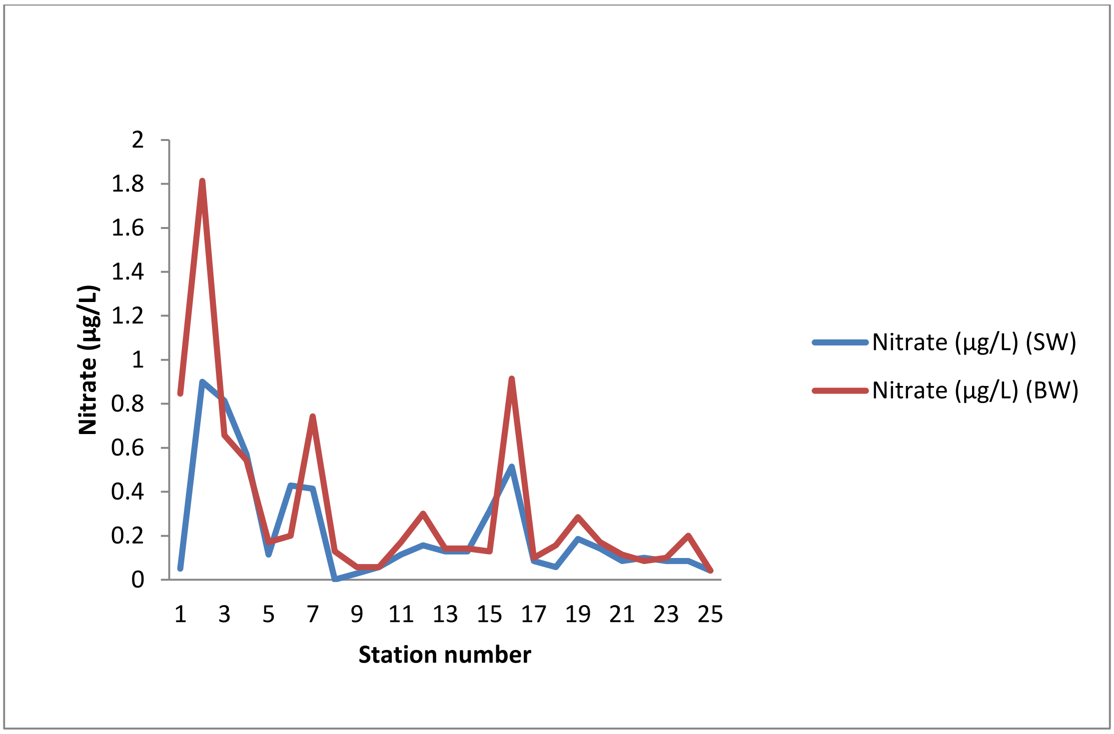

Fig. 8: Distribution of nitrate in the shelf waters off Karnataka Coast

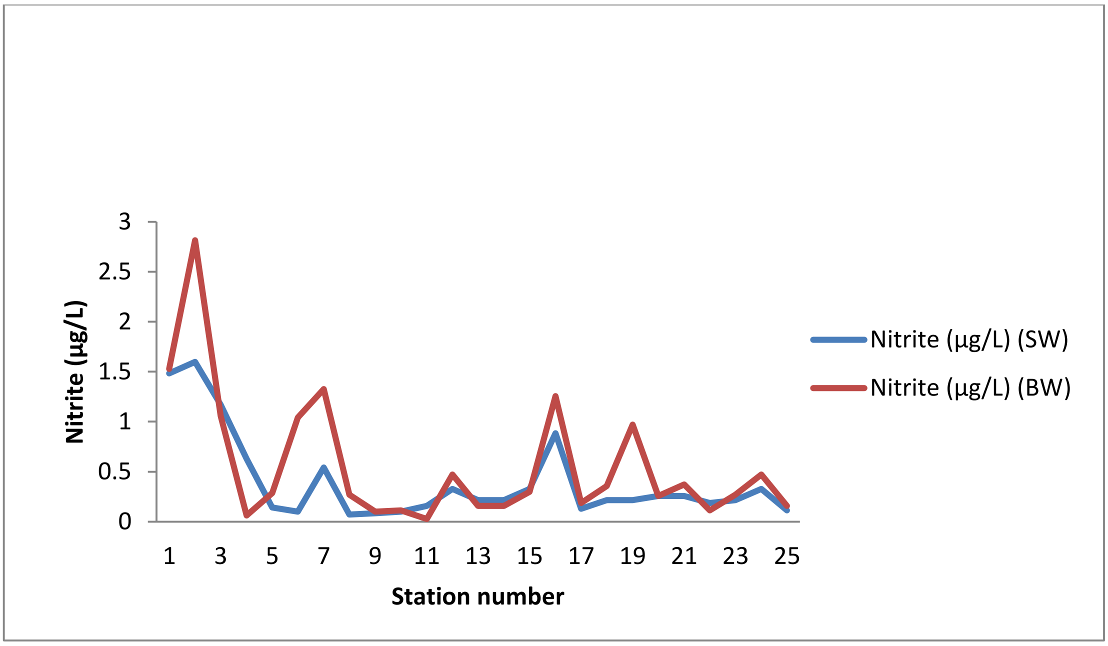

Fig. 9: Distribution of nitrite in the shelf waters off Karnataka Coast

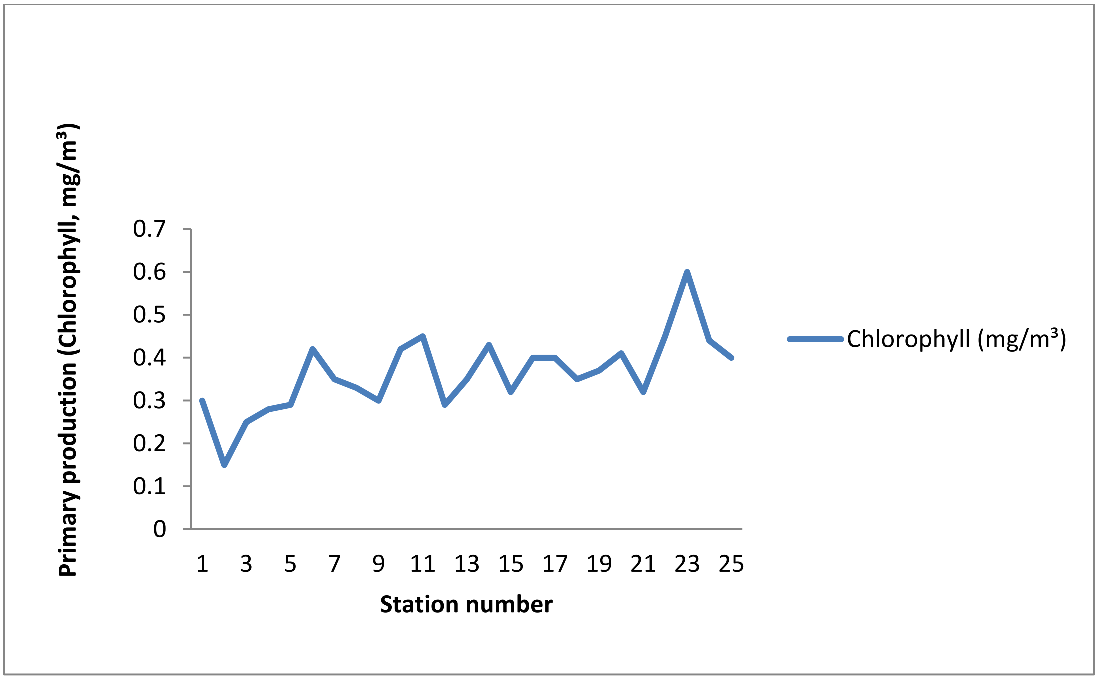

Fig. 10: Distribution of primary production (Chlorophyll, mg/m^3) in the shelf waters off Karnataka Coast

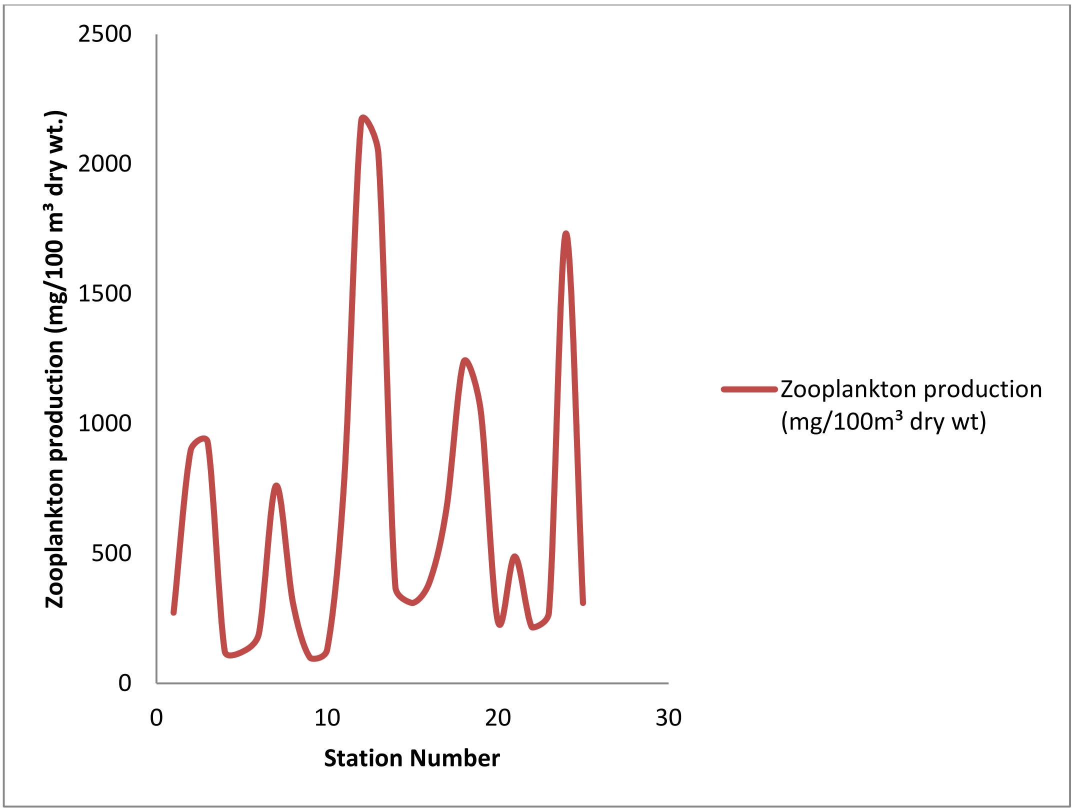

Fig. 11: Distribution of zooplankton production (mg/100m^3 dry wt.) in the shelf waters off Karnataka Coast

DISCUSSION:

One can distinguish three conspicuous Seasons along the west coast of India, which holds good even for the shelf waters. Due to enormous south-west monsoon wind in the period between June and September, heavy rain fall and a complete transformation of hydrological climate sets in, this period is called as monsoon period and the Seasons preceeding and succeeding it are called as premonsoon (February – May) and post monsoon (September – January) periods respectively. Because of this type of characterization, the role of Seasonal variation in this region has gained importance. The present study was carried out during the end of post monsoon period (June) and various waer parameters studied for surface and bottom waters are discussed here under, alongwith a note on the status of primary production and zooplankton production of the region.

TEMPERATURE

Variation in the surface and bottom water temperatures at the inshore, mid-shelf and shelf edge stations exhibited a somewhat uniform trend. The surface temperature was relatively less at the shelf edge stations (Mean temperature is 27.76°C) or mid-shelf (28.58°C) stations. However, the bottom water exhibited a drastic drop in its temperature value towards the shelf edge (Mean value is 22.76°C at shelf edge stations). The bottom water temperature of mid-shelf stations (28.3°C is mean value) was fairly high, though the area was deep, which might be due to vertical mixing of water mass.

Among the inshore stations, station 4 was the area of lowest surface water temperature (26°C) while station 16 showed highest (30°C). For bottom waters, station 22 was the area of lowest temperature (22.6°C) whereas station 17 recorded highest (29°C) as given in table-IV-A.

Among the mid-shelf stations, mnimum temperature (27.2°C) was observed at station 24, while maximum(15°C) was at station 15. For bottom waters, station 2 (25.7°C) and station 18 (30°C) were the areas of minimum and maximum temperature values (Table-IV-B).

At the shelf-edge, 26°C of station 8 and 29°C of station 13 and 14 were the lower and higher temperature values of surface water. Similar variation for bottom water was 12°C of station 8 (Table-IV-C). The trend in variation of surface and bottom water temperature is exhibited in Figure 2.

While studying the hydrological features of the coastal waters of North Kanara, Annigeri (1979) observed that there was a bimodal pattern in the surface temperature in the region. He observed the primary maximum (30°C) in April/May and a secondary maximum (28°C) during October/November. The minimum was around 27°C occurring in August/September. A similar investigation by Annigeri (1972) in the inshore region of Karwar showed that bottom temperatures were invariably lower than those above. The minimum and maximum temperatures at surface, 10 mtrs. And bottom were 27.5 and 30.4°C, 27.3 and 30.4°C, 27 and 30.3°C Radhakrishnan (1978) studied the hydrology at inshore waters of Mangalore. By him temperature of surface water was in a limit of 27.54°C – 30.50°C and of bottom water was in a limit of 26.94°C - 30.10°C.

According to Noble (1960) he observed that the pattern of temperature distribution is mainly due to the upwelling cold water invading the coastal area, while Ramamurthy (1963) relates the summer and winter maxima and the intervening minima to the two monsoons. Subrahmanyan (1959) attributes the secondary fall of temperature in December January period to the influence of Bay of Bengal waters brought by the coastal currents to the weat coast in a north wontorly direction which view finds agreement with the observations of Noble (1968) also. However, it is rather doubtful whether the influence of Bay of Bengal waters can be felt at those northern contros of the Kanara Coast.

While studying on hydrography of coastal waters of Cochin, Purohit (1988) was observed that the south west coast of India is influenced by south west monsoon; the associated currents and the upwelling phenomenon. pre-monsoon (June - September), it was varying from 23.00-24.00°C and lowering of temperature is due to Season of heavy rainfall. In post-monsoon Seasons (October January), temperature ranged from 28.00°C-29.00°C.

Observations by Ramamirtham (1960), showed that there was a gradual warming up of the surface water, the temperature varying between 29.5°C-30.15°C. Studies on the physical features of nearshore waters off Karwar by Gopinathan (1980), he observed that the waters of low temperature (less than 26.0°C).

Rao (1989) studied the short-term variability in the observed temperature of the north eastern Arabian Sea. By him, during summer (February-May) the surface layers in the Arabian Sea warm up due to excessive absorpt ion of solar radiation resulting in an increase in tempera ture by about 20°C-40°C. In *M. edulis*, temperature also influenced the byssal thread production with more threads produced during summer, a time of increased average temperature. However, despite the increased number of threads, overall tensile strength was weaker during summer (Yvette, 2013). According to Christopher *et al.* (2006) anthropogenic climatic forcing is mediated primarily by greenhouse gas (predominantly CO_2) emissions. Together, elevated CO_2 and the resultant increases in global mean temperature will result in a cascade of physical and chemical changes in marine systems. However, this Seasonal warming may not be monotonic and progressivethroughout the summer Season.

However, the temperature range between the maximum and minimum associated with the south-west monsoon is much greater than that of the north-east monsoon.

SALINITY

Estuaries are characterised by marked diurnal and Seasonal changes in salinity. The changes are brought about either by the tidal variations or by the influx of fresh water from rivers or land runoff caused by the monsoon system.

Salinity showed slight increasing pattern from inshore to shelf-edge stations. Salinity of surface water was comparatively low (31.43%o) at inshore station, at midshelf station it enhanced (31.97%o) and again at shelf-edge station, it was decreased (31.64%o). Bottom water showed a clear pattern. Low salinity (31.51%) was observed at inshore stations, it was increased uniformely at mid-shelf (32.38%o) and shelf-edge stations (33.58%). Bottom water showed fairly high saline water.

Among the inshore stations, station 3 was the area of lowest surface salinity (30.40%o) while station 17 showed highest (32.58%o). For bottom waters, station 16 was having the lowest salinity (30.90%) and station 22 was having the highest (32.92%) as given in table-IV-A.

At the mid-shelf stations, 31.41% and 32.33% at station 2 and 18 respectively were the lower and higher salinity values of surface water. Similar variation for bottom water was 31.66%o of station 2 and 33.00%o of station 24 (table-IV-B). Among the mid-shelf stations, at station 2, the salinity was fairly high.

Among the shelf-edge stations, minimum salinity at surface (30.99%o) was observed at station 14, while maximum (33.84%o) was observed at station 25. For bottom waters, station 1 (31.22%o) and station 19 (35.85%) were the areas of minimum and maximum salinity values (table-IV-C).

The trend in variation of surface and bottom water salinity is showing that, the salinity of bottom water was comparatively high (Figure 2).

Other than the depth, one more factor which could be considered is the presence of four major estuarine systems along the study stretch (figure 1),therefore the lowering of salinity at the inshore stations can be partly attributed to the impact of these riverine discharges.

While on the investigation of hydrography of coastal waters of Cochin, Purohit (1988), showed that during premonsoon Season, surface salinity was within the limit of 33.00% - 36.00%o, in monsoon Season within the limit of 33.00%o - 34.50% and in postmonsoon Season, 34.50%to 35.50%. He also observed that the current system was still stronger in November and the Arabian Sea water existed along the surface region. But the reversal of current towards north was observed by January and this brought the low salinity equatorial surface water along the surface and a rapid sinking of Arabian Sea water takes place. The phenomenon of upwelling dissappeared by October.

Investigations by Radhakrishnan (1978) on hydrology in the inshore waters of Mangalore revealed that surface water salinity was in a limit of 33.01% - 35.63% in November and May respectively, whereas of bottom water salinity was in a limit of 33.14-35.60%, minimum in November and maximum in May respectively. This annual variation of salinity indicatod a situation which was different from the bimodal annual temperature variation. Rainfall was invorsely related to the salinity variation in the inshore waters. While studying on physical features of nearshore waters of Karwar by Gopinathan (1980), he observed high salinity (more than 35.50%) except during August - October.

While studying the hydrologiasl features of the coastal waters of north kanara, Annigeri (1979) coserved that, salinity attains its maximum (35.00%) in September October and remins steady for a long duration. From June, it rapidly falls to its minimum (12 +- 2%) in July/August. Karvar seems to be influenced more by the incursion of fresh water of Kali River which is primarily responsible in bringing down the salinity lower than rest of the contros. A similar investigation by Annigeri (1972) in the inshore region of Karwar showed that, the average salinities flugtusted within narrow limits, the maximum and minimum at an urface being 34.91% and 34.41%, and at bottom 35.07% and 34.51%.

Rao and George (1960) stated that the salinity distribution in estuaries are controlled by tide. Special observations by Ramamirtham (1960) on hydrographical features of the continental shelf waters off Cochin showed that, during December, the salinity of the shelf waters varied only between 33.00% - 34.00% and during January, between 32.00% 33.00%. Just outside the shelf, there - was salinity increased and the notable feature was, salinity was low and vertical distribution is more or less uniform all along the shelf. There was much difference in the salinities of inshore and offshore waters on the shelf and also beyond.

DISSOLVED OXYGEN

Dissolved oxygen at the inshore, mid-shelf and shelf-edge stations, surface and bottom water DO exhibited a somewhat uniformely increasing trend (Table-IV). The surface dissolved oxygen was relatively less (3.07 ml at NTP/L). It was moderately increased at mid-shelf station (3.60 ml at NTP/L) and again it was increased at shelf-edge station (4.65 ml at NTP/L). However, bottom water dissolved oxygen exhibited a drastic drop. The bottom water DO at inshore station was low (Mean value 2.87 ml at NTP/L), at mis-shelf station, DO slightly raised (2.95 ml at NTP/L) and at shelf-edge station, again DO value raised (3.19 ml at NTP/L).

Among the inshore stations, station 17 was the area of lowest DO content (0.067 ml at NTP/L) at surface water, while station 3 showed highest (7.70 ml at NTP/L). For bottom waters, station 11 (0.50ml at NTP/L) and station 3 (7.45 ml at NTP/L) were the areas of minimum and maximum dissolved oxygen values (Table-IV-A).

At mid-shelf stations, minimum DO at sur face water (1.18ml at NTP/L) was observed at station 21, whil maximum (6.43m1 at NTP/L) was observed at station 2. For bottom waters, station 21 and 24 (0.67 ml at NTP/L) and station 12 (5.75 ml at NTP/L) were the areas of minimum and maximum dissolved oxygen values (Table-IV-B).

Among the sholf-edge stations, 1.01 ml at NTP/L of station 7 and 5.92 ml at NTP/L of station 1 for surface water, wore the lower and higher DO valuos. Similar variation for bottom water was 0.67 ml at NTP/L of station 8 and 5.92 ml at NTP/L of station 25 (Table IV-C).

The surface waters are found to be supersaturated with oxygen at the time of expedition, except in regions of upwelling. Dissolved oxygen values were found to be fairly high at shallower stations, whereas at depth stations, it was comparatively low. However, at certain deeper stations the DO content was high as contrast to the expectations which may be attributed to the circulation pattern of the region. The pattern of oceanic circulation of the study period is as clockwise gyral in the Arabian Sea. This must have kept the DO concentration at a fairly higher side.

The oxyty in the surface layer was nearly uniform, indicating effective mixing in this layer revealed that the oxygen maxima are due to the transport of oxygen rich subtropical subsurface waters accross the equator. The high oxyty of the bottom waters has been attributed to the penetration of the water mass origenating in circumpolar regions.

D'souza and Sastry (1973) have worked on the oceanography of Arabian Sea during south-west monsoons Dissolved oxygen, and formed a continuation of the earlier studied by authors (Sastry & D'Souza, 1970 a, b & Sastry & D'Souza, 1971) to understand the oceanography of the region. They observed that the surface oxyty found to vary from 3.45-5.13m1/1. At intermediate layer, oxygen minimum layer was demarcated only in the northern Arabian Sea. South of 15°N, oxyty maxima was frequently observed in the intermediate layer. Along 15°N in the oxygen minimum layer (0.5m1/1 oxypleths) the oxyty shows a general increase to the west. Below the intermediate layer, the oxyty gradually increases with depth.

Observations on physical features of nearshore off Karwar by Gopinathan (1980), he observed the low dissolved oxygen (less than 3 ml/lit) except during August - October at depth more than 5 mtr. While studying the hydrological conditions in the inshore region of Karwar, he observed that variation of average monthly dissolved oxygen in surface waters was 4.14 - 5.77 ml/1 and 3.63 - 4.54 ml/1 and in bottom waters, the dissolved oxygen was 3.90 -5.92 ml/1, 3.27 - 7.66 ml/1 during two years duration. While studying the coastal waters of North Kanara, the mean monthly range of dissolved oxygen was from 3.4-5.6 ml/1 as against 2.8 5.3 ml/1 and 3.0-5.6 ml/1 recorded by Ramamurthy (1963) and Noble (1968) respectively.

While studying on hydrography of coastal waters of Cochin, Purohit (1988) stated that, in promonsoon the DO value ranged between 4.2 5.00 ml/l, in monsoon Season, DO ranged between 4.60 4.80 ml/1 and in postmonsoon Season, it ranged between 4.30 to 4.90 ml/1.

It is well known that due to upwelling during the south-west monsoon months the hydrographical features of coastal waters are subject to quite large amount of changes in depletion of dissolved oxygen (Sewell, 1965; Banse, 1959; Carruthers *et al.*, 1959; Sastry, 1959; Qasim, 1965).

From inshore stations to the shelf-edge stations showed a increased dissolved oxygen. It is possible that mixing by wind action might have contributed for the rich oxygenated layers.

The trend in variation of surface and bottom water dissolved oxygen is exhibited in Fig. 4.

pH (Hydrogen in concentration)

The surface pH was relatively high (7.89) at inshore stations than mid-shelf station (7.85) or shelf-edge station (7.93). Here pH was increasing towards the shelf-edge. But for bottom water, pH was decreasing towards the shelf-edge. At inshore station, pH was 7.76, at mid-sheld station, it was 7.77 and at shelf-edge stations, it was (8.03) fairly high.

Generally pH in the coastal waters increases than the normal values due to the discharge of chemical effluents. pH exhibited a perfect linearity with depth and salinity. Generally pH at surface water was uniformely distributed at inshore, mid-shelf and shelf-edge stations but at bottom water, it was in increasing pattern from inshore to shelf-edge stations.

Among the inshore stations, station 17 was the area of lowest surface water pH (7.50) while station 3 showed highest (8.68). For bottom waters, stations 10. 22 & 23 were the area of lowest pH (7.50) whereas station 3 recorded highest (8.86) as given in table-IV-A.

Among the mid-sholf stations, minimum pH (7.50) was observed at stations 12, 21 & 24, while maximim pH (8.61) was at station 2. For bottom waters, stations 9, 12, 15, 18 & 24 (7.50) and station 24 (8.66) were the areas of minimum and maximum pH values (table-IV-B). The trend of pH values does not show any significant variation for surface and bottom waters (Fig. 5).

Generally pH decreases with increasing in depth. Venkataswamy Reddy (1986) studied on the hydrographic conditions of the inshore waters of Mangalore. He revealed that, the pH values i.e., Efficient co-efficient values were generally low after the south-west monsoon Season and higher during the September could due to the increased turbidity of the water during the preceeding south-west monsoon.

Observations on the hydrological features of the coastal waters of north Kanara by Annigeri (1979) showed that, during the monsoon months the pH values were lowered than 8.2 and during pre and postmonsoon months the values were higher than 8.2. Monthly mean values of pH varied from 8.2- 8.4 during November-May and from 7.9 -8.2 during June - September. In these two periods, Ramamurthy (1963) recorded the range as 8.4 - 8.5 and 7.4- 8.3 and Noble (1968) 8.2 -8.4 and 7.8 - 8.3 respectively. The study of Haresh *et al.* (2022) reveals that water quality parameters like pH, salinity, dissolved solid, oxygen, turbidity, sulphate and nutrients are impacted by the anthropogenic activities and tidal influence. The decline in pH values during July-September at Karwar was more marked because of the influx of Kali River water into the Bay.

SUSPENDED LOAD

Suspended load concentration was increasing towards the shelf-odge. At inshore stations it was relatively low (19.00 mg/L), at mid-shelf it was 20.25mg/L and at shelf-edge it was fairly high (21.38 mg/L). A clear increasing pattern was observed from inshore to shelf-edge stations.

At inshore station suspended load varied between 12.6 - 30.0 mg/L at station 22 and 4 respectively (Table-IV-A). At mid-shelf station, suspended load at station 15 and 24 ranged from 15.8 - 25.8 mg/L respectively (Table-IV-B). At shelf-adge stations, suspended load was low (16.8 mg/L) at station 25 and rich (28.0 mg/L) at station 14 respectively (Table-IV-C). The trend of suspended load at different stations is exhibited in Fig.6.

Investigations on distribution of suspended matter in waters of north-western shelf of India by Rao (1976) showed that the suspended matter in surface water varied from 0.3 to 4.6 mg/L while at the bottom, it varied from 0.5 to 13.6 mg/L. High concentration of suspended matter in its coastal water and in the vicinity of river mouth was due to inert material. In regions away from the coast higher concentrations of suspended matter were presumably due to a greater plankton production.

Rao and Rajamanickam (1976) studied on the distribution of suspended matter in waters of North-Western shelf of India. It indicated that, the concentration of suspended matter in surface water varied from 0.3 - 4.6 mg/L. while at bottom, it varied from 0.5 13.6 mg/L. High concentration of suspended matter in a constal waters and in the vicinity of river mouth was due to the inert material. In regions away from the coast higher concentrations of suspended matter were presumbly due to a greater plankton production. Main sources of suspended matter in the ocean are river run-off, biological activity and Colin dunt, intense coastal abrasion and churning up of sedimentary material. Study of regional variations of the suspended matter indicates the occurance of high concentrations near the river mouths. The strip of high suspended matter abos not spread wider which may probably be due to the presence of strong long shore currents which do not permit its dispersel very far off the shore. Lower concentration of suspended matter may be due to the arid condition generally prevailing on land and because of the absence of rivers.

If the concentration of suspended mattor decreases from the coast both in surface and bottom waters, it may be due to either resuspension of bottom sediments by the activity of bottom currents or settling of bulk of sediments quickly to the bottom and dispersal offshore by the bottom currents. If the concentration at surface and bottom waters increases from the coast, it indicates the main direction of dispersal and the currents elevation in the area. Intermediate values may be due to the influence of the rivers which brings a considerable amount of sediment which gets dispersed over a area.

Vertical Extinction Coefficient (V.E.C.)

At inshore stations, V.B.C. was 0.1543 m. which was showing comparatively less turbid water, at mid-shelf stations, it was 0.1479 m. and at shelf-edge it was very low 0.1214 m.

Vertical extinction coefficient was decreasing towards the shelf-edge stations. Among inshore stations, y.E.C. was in a range of 0.1214 - 0.1889 m. at stations 3 & 4 and station 17 respectively (Table-IV-A).

Among mid-shelf stations, values were ranging from 0.0850 - 0.1889 m. at station 5 and station 9 respectively (Table-IV-B).At shelf-edge, V.E.C. at station 1 was 0.1214m. (Table IV-C). The trend of V.E.C. was showing increasing pattern towards the shelf-edge.

Venkataswamy Reddy *et al.* (1986) while studying on hydrographic conditions of the inshore waters of Mangalore, he observed that the V.E.C. values were generally low in the south-west monsoon and higher in the premonsoon Season, this could be due to the increased turbidity of the water during south-west monsoon. The amount of light transmitted through depends upon the nature of material suspended in it, which in turn depends on the input of suspended material, turbulance and also the position of the sun in sky during the observation, cloudiness and molecular processes in the water body.

Increased turbidity of the waters brought about by the land drainage during the south-west monsoon Season.

Observations on light transmission characteristics of the northern Arabian Sea by Varkey and Kesavadas (1976) showed that, the values of attenuation coefficient (ED) were computed for layers of 5m thickness. A minimum value of 0.067 was observed off port Dabol south of Bombay corresponding to a 1% level of 68m. In very turbid Gulf of Cambay the 1% level occured very close to the surface and a high ED value of 4.6 was noted corresponding to a 1% level of 1m. Based on the values of BD, the marine environment could be divided into three categories (1) Oceanic (ED < 0.15), (11) Coastal (0.15 > ED > 0.46), (11ii) very turbid (ED < 0.46).

In the Gulf of Cambay and nearby areas transparency was greatly affected by sediment churned up by strong tidal currents.

The trend was showing that towards the shelf-edge the V.S.C. decreases (Fig. 7).

PHOSPHATE (PO_4 - P)

The nutrient concentrations of the bottom waters at the inshore stations were lower when compare with the deeper stations. Phosphate values gradually increased towards the mid-shelf and shelf-edge stations.

The surface phosphate content was relatively less at the inshore stations (Mean phosphate concentration is 0.107 µg at/L) than the mid-shelf (0.144 µg at/L) or shelf-edge (0.118 µg at/L) stations. Bottom water phosphate content at inshore stations were low (0.098 µg at/L) than the mid-shelf (0.155 µg at/L) and shelf-edge (0.201 µg at/L) stations.

Among the inshore stations at surface water, 17 was the area of lowest phosphate content (0.044 µg at/L) while station 11 & 23 showed highest (0.155 µg at/L). For bottom waters, station 4 was having the lowest phosphate content (0.016 µg at/L), at station 23 the phosphate contents was highetst (0.150 µg at/L) as given in table-IV-A.

Among the mid-shelf stations, minimum phosphate content at surface I 0.044 µg at/L) was observed at station 15 & 24, while maximum (0.500 µg at/L) was observed at station 9. For bottom waters, station 5 (0.011 µg at/L) and station 9 (0.444 µg at/L) were the areas of minimum and maximum phosphate content (Table-IV-B).

At the shelf-edge stations, 0.061 µg at/L and 0.261 µg at/L at station 14 & station 1 respectively were the lower and higher phosphate concentration values of surface waters. Similar variation for bottom water was 0.044 µg at/L at station 20 and 0.667 µg at/L at station 14. For bottom water phosphate content was increasing towards the shelf-edge (Table-IV-C).

Generally concentration of nutrients were higher in bottom water than surface water. Distribution of phosphate suggests that the availability of this nutrient is adequate to meet the required demand of primary producers. During the high biological active movement period lower values of phosphorus were observed by Kesava Rao (1989). Physical chemical processes are more important than the biological processes in determining the phosphate distribution in the estuary during monsoon.

While studying on particulate organic matter in coastal waters of Goa, Verlencar and Qasim (1985) was observed that, the particulate phosphorus during post and premonsoon periods was varied from 0.70 - 5.18 µg at/L. These were comparable to the particulate phosphate values ranging from 0.93 to 4.65 µg at/L reported by Rao & Rao (1975) from the coastal waters of Waltair (East coast of India).

Observations on the hydrographical features of coastal waters of North Kanara by Annigeri (1979), showed that the concentration of Phosphate at Karwar was lower than that of the other centres. This may be due to the freshening effect of river water which contains lower phosphate content. Ramamurthy (1963) also made a similar observations. Subrahmanyam (1959) observed a range of 0.131.68 µg at/L at Calicut and comparing the phosphate content of the different parts of the world, has shown that our coastal waters are very rich in Po; P. The ranges given by Noble (1968) are from 0.22 - 2.06 µg at/L and 0.11 2.44 µg at/L respectively and these values appear to indicate a richer phosphate content along the North Kanara coast than along the Calicut area. Similar investigation by Annigeri (1972) showed that, the variation of inorganic phosphate with depth showed that concentrations at the surface varied from 0.36 0.45 µg a t/L and at bottom, it varied from 0.44 0.79 µg at/L. Similar investigations by Annigeri (1980) on hydrography of the inshore waters off Karwar revealed that, the variation of average phosphate content at surface and bottom was 0.22 - 1.35 µg at/L and 0.32 1.55 µg at/L respectively.

While studying on hydrology of inshore waters of Mangalore, Radhakrishnan (1978), observed that the the general trend of inorganic phosphate indicated low values (0.13 - 0.15 µg at L) during December/January period with slight increase during the premonsoon period (0.15 0.18µg at/L).

The maximum phosphate values were observed during the south-west monsoon period (0.17 0.27 µg at/L). The trend in variation of surface and bottom water phosphate is exhibited in Fig. 8.

NITRATE (NO_3-N)

The surface nitrate was relatively less at the mid-shelf stations (Mean nitrate concentration is 0.217 µg at/L) than the inshore (Mean nitrate content 0.322 µg at/L) or shelf-edge (0.761 µg at/L) stations. However, the bottom water was showing a increasing trend towards the shelf-edge (1.562 µg at/L) was fairly high than inshore (0.361 µg at/L) and mid-shelf (0.367 µg at/L) stations.

Among the inshore stations, station 10 was the area of lowest nitrate content (0.056 µg at/L) at surface water while station 3 showed highest (0.814 µg at/L). For bottom waters, station 10 (0.057 µg at/L) and station 3 (0.856 µg at/L) were the area of lowest and highest nitrate concentration values (Table-IV-A).

At mid-shelf stations, munimum nitrate content at surface water (0.028 μg at/L) was observed at station 9, while maximum (0.900 μg at/L) was observed at station 2. For bottom waters, station 9 (0.057 μg at/L) and station 2 (1.814 μg at/L) were the areas of minimum and maximum nitrate concentration (Table-IV-B).

Among the shelf-edge stations, 0.000 μg at/1 at station 8 and 5.050 μg at/L of station 1 for surface water were the higher and lower nitrate content values. Similar variation for bottom water was 0.042 μg at/L of station 25 and 10.846 μg at/L of station 1 (Table-IV-C).

While studying on the hydrochemical characteristics off the central west coast of India, Sen Gupta *et al.* (1980) observed that about 34% of the available nitrate-nitrogen is depleted by denitrification. The standing crop of denitrified nitrogen is 70 gm $^{-2}$. Combining the rates of denitrification at an intermediate depth with the photosynthetic productivity at a euphotic zone, the mean residence time of the watermass is between 13 & 54 years. He found high values of nitrato at all stations during April/May could be attributed to oxidation of ammonical form of nitrogen to nitrite and subsequently to nitrate. Peak values recorded were proceeded by higher concentration of ammonia. The oxidation of ammonia to nitrite and then to nitrate may take place photochemically or chemically in a thin surface layer ar biologically in and near the bottom. The high values of nitrate-nitrogen might have been due to bacterial oxidation rather than photochemical oxidation of the high level to ammonia.

However, it is well known that organic nitrogen in dissolved form may be available for the direct utilization by phytoplankton to some extent (Guillard, 1963) and also as remineralisation products in the form of urea, ammonia and nitrates (Mc Carthy, Taylor and Jay, 1977).

During the low supply of nitrate to the estuary as is the case in premonsoon, the high phytoplankton production could probably be sustained by the reduced sources of nitrogen like ammonia and nitrite. Possible sources of ammonia input to these waters could be from land runoff, zooplankton excretion (Ketchum 1962) or remineralization of organic matter. The trend in variation of surface and bottom water nitrate concentration is exhibited in Fig. 9.

NITRITE (NO_2 - N)

Nitrite characterised by the presence of low concentration at surface and the increasing concentration at bottom.

At surface water, nitrite content was decreasing towards shelf-edge, the surface nitrite concentration was fairly high at the inshore stations (0.464 µg at/L) and decreasing towards the mid-shelf (0.410 µg at/L) and shelf-edge (0.210 µg at/L) stations. The bottom water showed a slight inverse relation for the distribution pattern. At inshore station the content was more (0.436 µg at/L), at mid-shelf stations suddenly the concentration was enhanced (0.771 µg at/L) and at shelf-edge stations, again it decreased (0.471 µg at/L).

Among the inshom stations, 0.100 µg at/L of station 10 and 1.171 µg at/L of station 3 were the lower and higher nitrite surface water values. Similar variation for bottom water was 0.061 µg at/L of station 4 and 1.051 µg at/L of station 3 were the lower and higher values (Table-IV-A).

At mid-s helf stations, minimum nitrite concentration at surface water (0.085 µg at/L) was observed at station 9 while maximum (1.600 µg at/L) was observed at station 2. For bottom waters, station 9 (0.100 µg at/L) and station 2 (3.815 µg at/L) were the areas of minimum and maximum nitrite content values (Table-IV-B).

At the shelf-edge, station 8 was the area of lowast nitrite concentration (0.000 µg at/L) at f surface water while station 1 showed highest (5.050 µg at/L). For bottom waters, station 25 (0.042 µg at/L) and station 1 (10.846 µg at/L) were the areas of minimum and maximum nitrite content values (Table-IV-C).

Increase in nitrite concentration in the off-shore station may be due to oxidation of ammonia to more stable forms of nitrogen. Increase in the concentration of nitrite in the offshore regions may be attributed to the bacterial de composition of planktonic detritus. The differences in Seasonal variation may be attributed by the variation in phytoplankton excretion, oxidation of ammonia and reduction of nitrate due to nitrifying bacteria.

While studying on distribution of nutrients in the coastal and estuarine waters of Goa, Verlencar (1987) observed that the nitrite at reference station varied from 0.02 - 1.18 µg at/L during post and premonsoon periods. Nitrite concentration of the offshore water column remained high during October-December. The nitrite concentrations at the estuary varied between 0.00- 1.71 µg at/L.

Observations on the hydrographical features of the coastal waters of North Kanara by Annigeri (1979) showed that, the nitrite distribution was so random that no annual rhythm could be seen in its distribution; 64% of the values lie between 0.0 - 0.6 µg at/L, 23% between 0.8 -1.50 µg at/L and only 13% between 1.6 -2.75 µg at/L. The nitrite values show no clear annual cycle exhibited and its content may depend on regeneration and consumption by the phytoplankton. Similar investigations on the hydrography of the inshore waters off Karwar by Annigeri (1980) observed that, the average nitrite values at surface and bottom varied from 0.03 4.77 µg at/L and 0.13 - 4.87 µg at/L respectively.

Observations on the hydrology in the inshore region of Karwar by Annigeri (1972) showed that, higher concentrations of nitrites were frequently met with below the surface. The range in minimum and maximum values at surface was from 0.05 - 3.00 µg at/L and at bottom from 0.13- 4.14 µg at/L. Earlier workers (Ramamurthy, 1963; Noble, 1968) have indicated a bimodal picture in the nitrite content, the first peak occuring during May - August and the second in December - January period. The range in minimum and maximum average value was 0.01 - 2.75 µg at/L by Annigeri (1979) whereas those given by Ramamurthy (1963) and Noble (1968) are 0.03 -3.59 µg at/L and 0.00 4.49 µg at/L respectively.

The trend in variation of surface and bottom water nitrite showed that the nitrite increases in their concentration from surface to the bottom (Fig. 10).

PLANKTONIC PRIMARY PRODUCTION

The transformation of inorganic matter into organic matter by photosynthesis to form plant material is the most important single factor governing the productivity of any region in the Sea. Chlorophyll and phosphate are among the more important factor deciding the primary productivity level in the Sea. The effluent discharge point shows increased plankton production. Phytoplankton abundance was found to be largely dependent on nutrient level. Population density of phytoplankton exhibited conspicuous diurnal variations and seems to largely dependent on tidal fluctuations. Viswanathan and Krishnamoorthy (1976) pointed out that, biomass data based on chlorophyll determinations are essential for assessing biological uptake of elements from the Sea.

Planktonic primary production at inshore station was fairly high (Mean value is 0.40 chlorophyll mg/m^3). At mid-shelf 3 area, it lowered (0.30 chlorophyll mg/m^3), at shelf-edge stations, again it increased (0.36 chlorophyll mg/m^3). At inshore station planktonic primary productivity varried between 0.25 to 0.60 chlorophyll mg/m^3 at station 3 and 23 respectively (Table-IV-A).

At mid-shelf stations, planktonic primary productivity value at station 2 and 24 ranged from 0.15-0.44 chlorophyll mg/m^3 respectively (Table-IV-B).

At shelf-edge stations, the planktonic primary productivity was low (0.30 chlorophyll mg/m^3) at station 1 and rich (0.43 chlorophyll mg/m^3) at station 14 respectively Table-IV-C).

While studying the particulate organic matter with relation to phytoplankton production in Gon, Denis and verlenenr (1985) found that the annual mean of surface chlorophyll and the primary productivity of the euphotic column in the estuari region were 4.3 mg/m^3 and 636.5 mg /m^3 respectively. They concluded that the chlorophyll and the organic phosphorus compounds are quickly decomposed, mineralised and denatured following the death of phytoplankton leaving a detrital recidue containing minly carbon and nitrogen. In environment like estuaries where the water mass is constantly renewed, the formation and decomposi tion of phytoplankton is relatively rapid leading to the accumulat ion of detritus. The observations on the annual cycle of chlorophyll and primary productivity of the estusrine stations by Verlencar (1984) showed surface chlorophyll concentrations to range from 0.5 - 11.3 mg/m^3 and primary productivity from 0.9 - 1205.5 mg C/m^3/day. Chlorophyll and primary productivity remained high in the begining of postmonsoon both at the ostuarine and coastal waters.

The high planktonic production may be due to the effect of nitrogenous effluents discharged in the area. However, nutrient requirement is known to differ with the phytoplankters and that high concentrations of nutrients along may not be conducive for substantial increase in productivity. Since the rate of regeneration of nitrogen is slower than that of phosphorus, the readily available ammonical form of nitrogen could have been responsible for high plankton production. By Segar and Hariharan (1989), the abundance of phytoplankton in December/January seems to be related to the increased nutrients contributed by the Netravati-Gurpur estuary during monsoon and postmonsoon Season and carried by the generally prevailing northerly drift during November/December.

In the southeastern Arabian Sea, Bhargava *et al.* (1978) timated that, in euphotic zone, daily primary productivity eraged 134 mg C/m^2/day in October and 357.9 mg C/m^2/day in cember and chlorophyll 'a' averaged 6.44 mg/m^2 & 10.6 mg/m^2 respectively.

Investigations on India and the Indian Ocean Fisheries by Raghu Prasad and Ramachandran Nair (1973) stated that, the average amount of chlorophyll a is found to be 25.41 mg/m^2 at west coast of India and on east coast, it is 8.24 mg/m^2 (Nair and Joseph, 1971). In the western Indian Ocean during southwest monsoon extremely high values of primary production (Prasad, 1970) and zooplankton biomass (Prasad 1968 a & b, 1969) were found mainly in the area off Cape Guardafui & Socotra in the upwelling region associated with Somali current. Such high values were not found during the north-east monsoon period apparently failing to provide any such nutritional enrichment in the open Sea. The distribution pattern of chlorophyll a showed that the level of pigment concentrat ion per unit area was almost the same to that of Atlantic and Pacific oceans even though the concentration per unit valume was slightly lower in the Indian Ocean (Humphrey, 1961).

Because of constant replenishment of nutrients in the surface layers, the shallow water areas of the tropics are generally productive. Observations on effect of salinity on pigment concentrations of some tropical phytoplankton by Bhattathiri and Devassy (1975) stated that, the salinity does not seem to influence the values of either chlorophyll c/a (or b/c) in carotenoid to chlorophyll a, though there is an overall difference in growth rates. Devassy and Bhattathiri (1981) at Little Andaman Island observed that, in shallow coral reef regions most of the organic matter production is by corals and Seaweeds occuring near the bottom and hence the increasing trend in chlorophyll values was found towards the subsurface levels. Devassy (1983) while studying on plankton production associated with cold water, into the estuarine environment he stated that, phytoplankton blooms comprising mainly of diatoms and dinoblagellates (< 0.55 million cells/L) and intense Zooplankton swarms (biomass 5.34 ml/m^3) were observed in the Mandovi and Zuari estuarine environ ment in October-November and pigment concentrations varied from 1.0-10.2 mg/m^3.

The low standing crops in the nutrient-rich patches with active phytoplankton population may be due to the high grazing pressure exhibited by the pelagic animal populations.

Investigations on primary productivity in the North-Estern Arabian Sea by Radhakrishnan *et al.* (1978) showed that, the productivity in the waters of shelf region averages 474.56 mg c/m^2/day, and was almost thrice the offshore average of 164.39 mg c/m^2/day. They pointed out that, the productivity in the shelf region was much higher than offshore. Chlorophyll a concentration varied from 0-1.5 mg/m^3 at the surface. However, the correlation between high intensity and chlorophyll a distribution was not significant in playing a patchy distribution of chlorophyll in the euphotic zone. The trend of distribution of planktonic primary productivity at different stations is exhibited in Fig.11.

PLANKTONIC SECONDARY PRODUCTION

There is no clear-cut relationship discernibler between primary productivity and secondary productivity. This may be due to the changing food habits of plankton. at inshore stations, the planktonic secondary productivity was relatively less (415.61 mg/100 m^3 dry wt.), than aid-shelf station (881.53 mg/100m^3 dry wt.) or shelf-edge 3 station (670.06 mg/100 m^3 dry wt.).

At inshore stations, planktonic secondary productivity was in a range of 123.80 - 928.50 mg/100 m^3 dry wt. at station 4 and 3 respectively (Table-IV-A). Among mid-shelf stations, values were ranging from 99.04 to 1733.0 mg/100 m^3 dry wt. at station 9 and 24 respectively (Table-IV-B). At shelf-edge stations, planktonic secondary productivity varied from 24.41 - 2042.70 mg/100 m^3 dry wt. at station 20 and 13 respectively (Table-IV-C).

The observations on the dissolved organic nutrients and phytoplankton production in Mandovi ostuary Goa by Verlencar (1984) showed zooplankton biomasn varied from 0.3 - 20.7 gm dry wt. 1000/m^3. At the estuarine regions, the peaks of zooplankton bioms as almost coincided with the packs in chlorophylla and primary productivity especially in June and October.

While studying on effect of Industrial effluents on biota at off Mangalore, Devassy *et al.* (1987) observed that, the biomass ranged from 0.004 - 0.38 ml/m^3, the lowest was recorded in December and highest in January. Although no apparent relationship could be seen between phytoplankton population and zooplankton bioman. Industrial effluents are reported to adversely affect the sooplankton biomass and population density. Annual production of vegetation is an important indicator of various ecosystem processes in coastal marshes; many factors, both biotic and abiotic, can influence the production of aboveground biomass (Joydeep *et al.*, 2009). Christopher (2018) stated that how biological and physical gradients regulate oyster recruitment, survivorship and growth will help guide future efforts to successfully restore oyster populations.

The trend of distribution of planktonic secondary productivity at different stations is exhibited in Fig. 12.

SUMMARY:

Results of a comprehensive hydrographical sampling programme of the shelf waters of Karnataka const is presented. The study trip was conducted on tha R.V.Gave shani Cruise No. 208 during 10-20th January 1989. Eight transects across the shelf, covering 25 stations were studied. Depth of stations varied from 17 to 1650 m. Findings of present study is described in brief here:

1. Hydrographical parameters studied are Temperature, Salinity, pH, Dissolved oxygen, Suspended lond, V.E.C., Phospha to, Nitrato, Nitrite of surface and bottom waters.
2. Biotic factors presented here are planktonic primary production (Chlorophyll mg/L) and planktonic secondary production (mg/100 m^3 dry wt).
3. Mean surface water temperature at inshore, midshelf and shelf edge stations were 27.6°C, 28.1°C and 28.58°C respectively. Mean bottom water temperature at shelf edge was 22.76°C.
4. Salinity showed slight increase from inshore to shelf edge stations. Salinity of surface waters was comparatively low (31.43%). Lowering of salinity at the inshore stations may be partly due to the reverine discharge all along the coast.
5. Dissolved oxygen at the inshore, mid-shelf and shelf-edge stations, surface and bottom DO exhibited a somewhat uniformely increasing trend. The surface dissolved oxygen was relatively less (3.07 ml at NTP/L). But bottom exhibited a very low DO content.
6. The surface pH was relatively high (7.89) at inshore stations than mid-shelf (7.85) or shelf-edge (7.93) stations. pH was increasing towards the shelf-edge. But for bottom water, pH was decreasing towards the shelf-edge.
7. Suspended load concentration was increasing towards the shelf-edge. At inshore stations it was relatively low (19.00 mg/L), at mid-shelf it was 20.25 mg/L and at sholf-edge it was fairly high (21.30 mg/L). A clear increasing pattern was observed from inshore to shelf-edge stations.
8. V.E.C. at inshore stations (0.1543 m) was 8 showing relatively low turbid water, at mid-shelf stations it was 0.1479 m and at shelf-edge it was very low 0.1214 m.
9. The bottom water phosphate concentrations were lowered at inshore stations (0.09849 µg/L) than other stations. Phosphate content was gradually increased towards the mid-shelf (0.155 µg at/L and shelf-edge I 0.201 µg at/L) stations. The surface phosphate content was relatively low at the inshore (0.107 µg at/L) stations

than the mid-shelf (0.144 µg at /L) and shelf-edge (0.118 µg at/L) stations. Generally concentration of nutrient was higher in bottom water than the surface water. Physical-chemical process are more important than the biological process in determining the phosphate distribution in the estuary during monsoon.

10. The surface nitrate was relatively low at the mid-shelf (0.217 µg at/L) than the inshore (0.322 µg at/L) or shelf-edge (0.761 µg at/L) stations. However, the bottom water showed a increasing nitrate concentration towards the shelf-edge (1,562 µg at/L) than inshore (0.361 µg at/L) and mid-shelf (0.367 µg at/L) stations. The high values of nitrate-nitrogen might havo been due to bacterial oxidation rather than photochemical oxidation of the high level to ammonia.
11. Nitrite characterised by the presence of low concentration at surface and the increasing concentration at bottom. Increase in the nitrite concentration in the offshore regions may be attributed to the bacterial decomposition of plankton detritus. Increase in nitrite concentration in the offshore stations may be due to oxidation of ammonia to more stable forms of nitrogen.
12. Planktonic primary production at inshore station was fairly high (0.40 chlorophyll mg/m^3). At midshelf area it was lowered (0.30 chlorophyll mg/m^3). At shelf-edge stations again it increased (0.36 chlorophyll mg/m^3). The transformation of inorganic matter into organic matter by photosynthesis to form plant material is the most important single factor governing the productivity of any region in the Sea.
13. Planktonic secondary production was relatively less at inshore (415.61 mg/100 m^3 dry wt) than mid-shelf 3 (881.53 mg/100 m^3 dry wt) or shelf-edge (670.06 mg/100 dry wt) stations. There is no clear-cut relationship discernibler between primary productivity and secondary productivity. This may be due to the changing food habits of plankton.

Results presented here is on the basis of a sampling trip conducted during the end of Post-monsoon period, thus providing information on the spatial pattern of various paramo tors. Information on temporal (Seasonal) variation is essential in order to define the hydrographic dynamics of shelf waters of the region over the temporal sequence.

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