Biological Oceanography of the Bay of Bengal

By

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Until the latter half of the present century, the Bay of Bengal was one of the least explored parts of the northern Indian Ocean except for the work carried out by Col. Seymour Sewell on board R.I.M.S.S. *Investigator* in the eastern and southern part of the Bay and published in a series of papers in the Memoirs of the Asiatic Society of Bengal (1929, 1932). After a gap of nearly two decades the Andhra University, Waltair, under the inspiring leadership of Prof. E. C. La Fond, organised a series of 56 Oceanographic Cruises in the south-western part of the Bay of Bengal ranging from Madras in the south to the Swatch of No Ground in the north. Most of the investigations were centred off the Visakhapatnam Coast and the valuable data from over 700 stations were published in the two volumes of the Andhra University Oceanographic Memoirs (1954, 1958). La Fond (1958) has summarised the results of these investigations which covered the physical, chemical, geological and biological aspects. The next notable impetus to the Oceanographical studies in the Bay of Bengal came with the launching of the International Indian Ocean Expedition Programme (IIOE) during the years 1960-65. Many ships of the participating countries like *Vityaz* (U. S. S. R.), *Anton Bruun* (U. S. A.) and *Pioneer* (U. S. A.) collected some valuable data from the Bay of Bengal. The Directorate of Indian Ocean Expedition actively participated in the Indian Programme of the IIOE and with the co-operation of the Indian Navy several cruises were conducted on board I. N. S. *Kistna* in the Bay of Bengal during 1963-65. Several papers on the Physical, Chemical, Geological, Geo-physical and Biological aspects of the Bay of Bengal were presented at a Symposium on Indian Ocean, under the joint auspices of the Indian National Science Academy and the Indian National Committee on Oceanic Research held at New Delhi on March 2-4, 1967. These papers have since been published as a special bulletin of the Indian National Science Academy in two parts (Bull. Nat. Inst. Sci. India, 38, Part I, 1968; Part II, 1969).

Hydrographical Conditions of the Bay of Bengal

The Bay of Bengal is unique in many respects. All the major river systems in India and Burma empty into the Bay of Bengal. It has been estimated that as much as 1300 million acre feet of fresh water is drained, on an average, per annum into the Bay, by the rivers, Irravadi, Ganga, Brahmaputra, Mahanadi, Godavari, Krishna and Cauvery. This water if uniformly spread over the Bay is sufficient to raise its level by 5 feet (Khosla, 1949, Lotka, 1956). The inundation by such enormous amounts of fresh

water renders the surface water of the Bay, almost estuarine, during the post-monsoon months, September and October, while near marine conditions are present from January to June. In addition, large scale discharge of silt by the rivers, reduces the transparency of the water over large areas in the Bay with a consequent fall in the rate and quantum of photosynthesis.

A second unique feature of the Bay is the influence of the south-west monsoon winds which bring about a complete reversal of the surface current pattern which is clock-wise from January to July and counter clock-wise from August to December, according to the direction of the wind (Fig. 1).

The temperature, salinity and density of the water masses depend entirely on the current systems. The annual range of temperature is 25–29°C while the

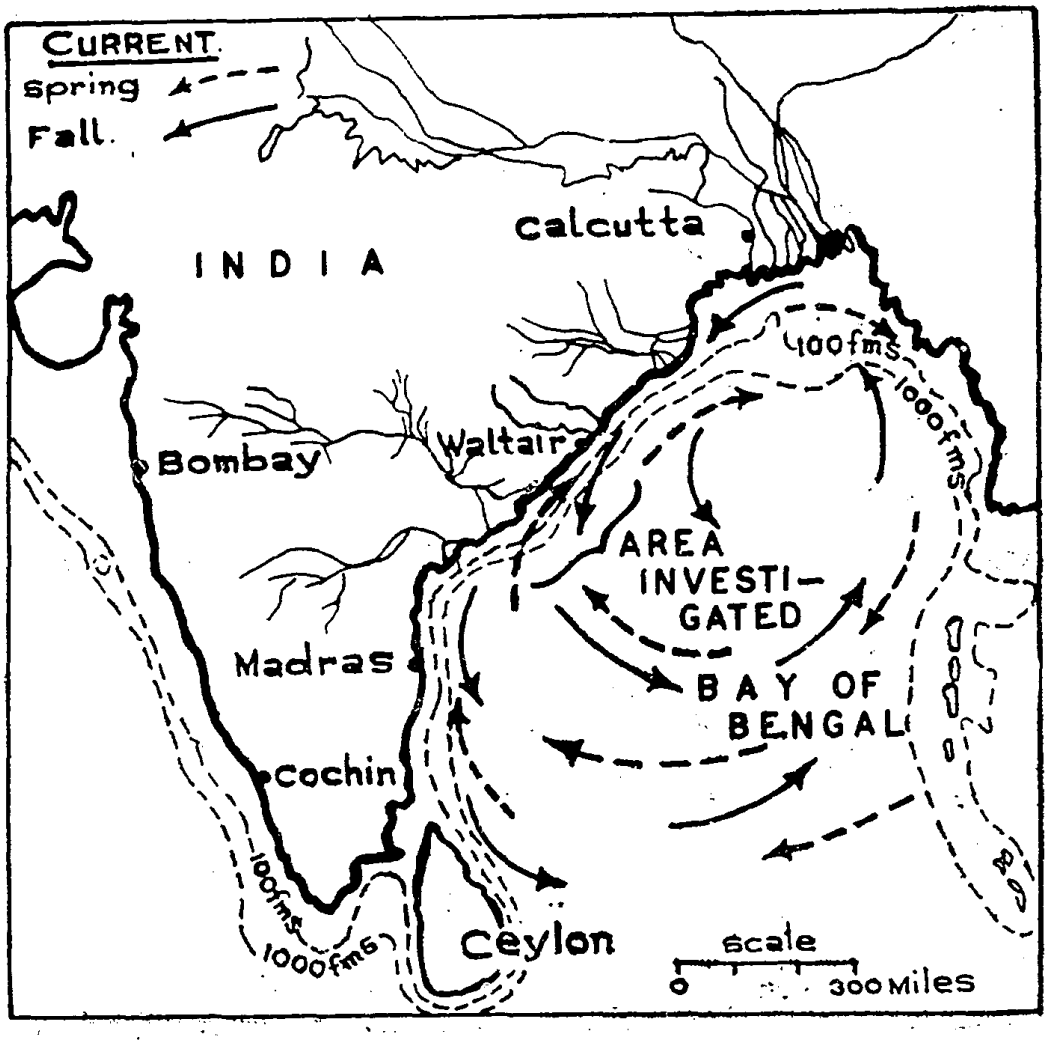

Fig. 1. Showing the Surface Currents in the Bay of Bengal

salinity may vary from 20–33‰. The isohaline of 34‰ and above is almost always outside the Bay.

The seasonal temperature-salinity (T-S) relationship in the Bay of Bengal is specific and is continually renewed at nearly the same season, from year to year. Based on the T-S plot of the surface and sub-surface waters, La Fond (1958) has designated as many as 6 different surface and sub-surface water masses based on their density or Sigma-*t* (σt) limits (Fig. 2). A Northern Dilute Water (σt <19) from October to December; a Transition Water Mass (σt = 19–21) from January to February and August to September and Southern Bay of Bengal Water (σt = 21–22) in February. The three sub-surface water masses are the Upwelled Water Mass (σt = 22–23); the sub-surface Shelf Water Mass (σt = 23–24) and the Indian Equatorial Water (σt < 24) (La Fond, 1968). In the North Indian Ocean the main deep water mass is the Indian Equatorial Water which covers the Central Indian Ocean and extends into the Arabian Sea and Bay of Bengal. The surface waters in the Bay are always warm and low saline while the cold high saline waters are always in the sub-surface layers except during periods of turbulence, upwelling etc. Such a stratification is not favourable for large scale mixing processes which are necessary for the transport of plant nutrients from the sub-surface to the surface layer, for effective photosynthesis. The 'thermocline' or discontinuity layer in the Bay varies with season ranging from 50–125 metres.

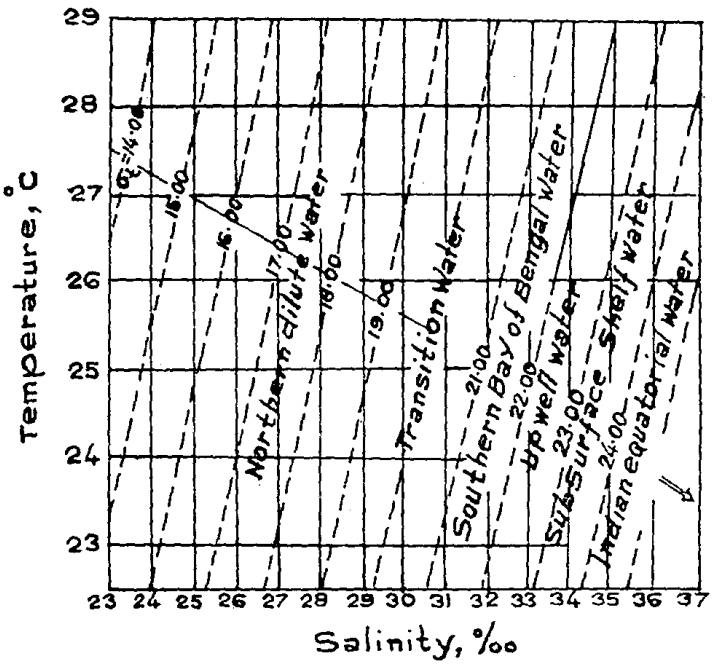

Fig. 2. Temperature Salinity diagram and related sigma-t. Shallow water masses for Bay of Bengal are named and assigned sigma-t limits (La Fond, 1958).

Large scale upwelling has been reported along the east coast of India by many workers during the pre-monsoon and monsoon periods. Areas where large scale upwelling takes place are also areas of high phytoplankton production.

Sankaranarayanan and Gangadhara Reddy (1968) found low phosphate values in the surface water of the north-

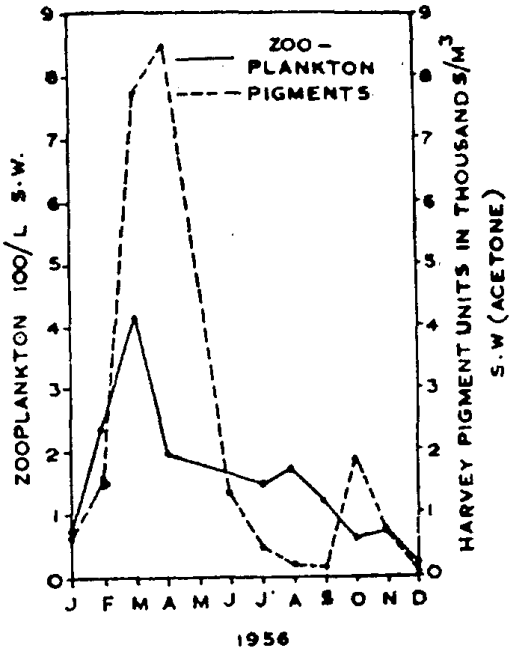

Fig. 3. Showing the mean monthly values of pigments and zooplankton organisms in the surface waters off Lawson's Bay during the year 1956.

western Bay of Bengal with maximum concentration of the nutrient at depths of 600–800 metres. The nitrate values were also high between 300–800 metres while the silicates showed a continuous increase with depth. Chalapathi Rao and Satyanarayana Rao (1968) also found low total phosphate content in the surface waters off Visakhapatnam, Nicobar Sea, Andaman Sea and off the Burma Coast. An increase of total phosphate was observed by the above authors up to 500 metres.

Productivity

It is generally accepted that the east coast of India bordering the western part of the Bay of Bengal is less productive than the west coast bordering the Arabian Sea. Almost 75 per cent of the total fish landings from India are from the west coast. Panikkar and Jayaraman (1956) attribute the high fish yield on the west coast to the favourable hydrological conditions, such as stable salinity approximating oceanic waters, rich nutrients, particularly phosphates in the mud banks off Malabar Coast and perhaps also the better organisation and exploitation of the fisheries on the west coast as compared with the east coast. In contrast we have very unstable salinity conditions in the Bay, which is estuarine through most of the year; the constantly changing surface water masses and the stratification of the surface and subsurface layers owing to wide differences in temperature and salinity and consequent density. Such a situation, as already pointed out, is not conducive to large scale mixing which is essential for the replenishment of the plant nutrients in the surface waters, where primary production takes place.

It is interesting to note that the primary peak of both phytoplankton and zooplankton blooms occur during the pre-south west monsoon months, January to April when the current is in a northerly direction bringing in the warm saline nutrient rich Indian Equatorial Waters into the Bay (Fig. 3&4). It is also known that the nutrient rich Antarctic Bottom Waters moving in the direction of the Carlsberg submarine ridge upwell in the southern part of India and Sri Lanka (Ceylon), one branch going westward in the direction of the Laccadive – Maldive

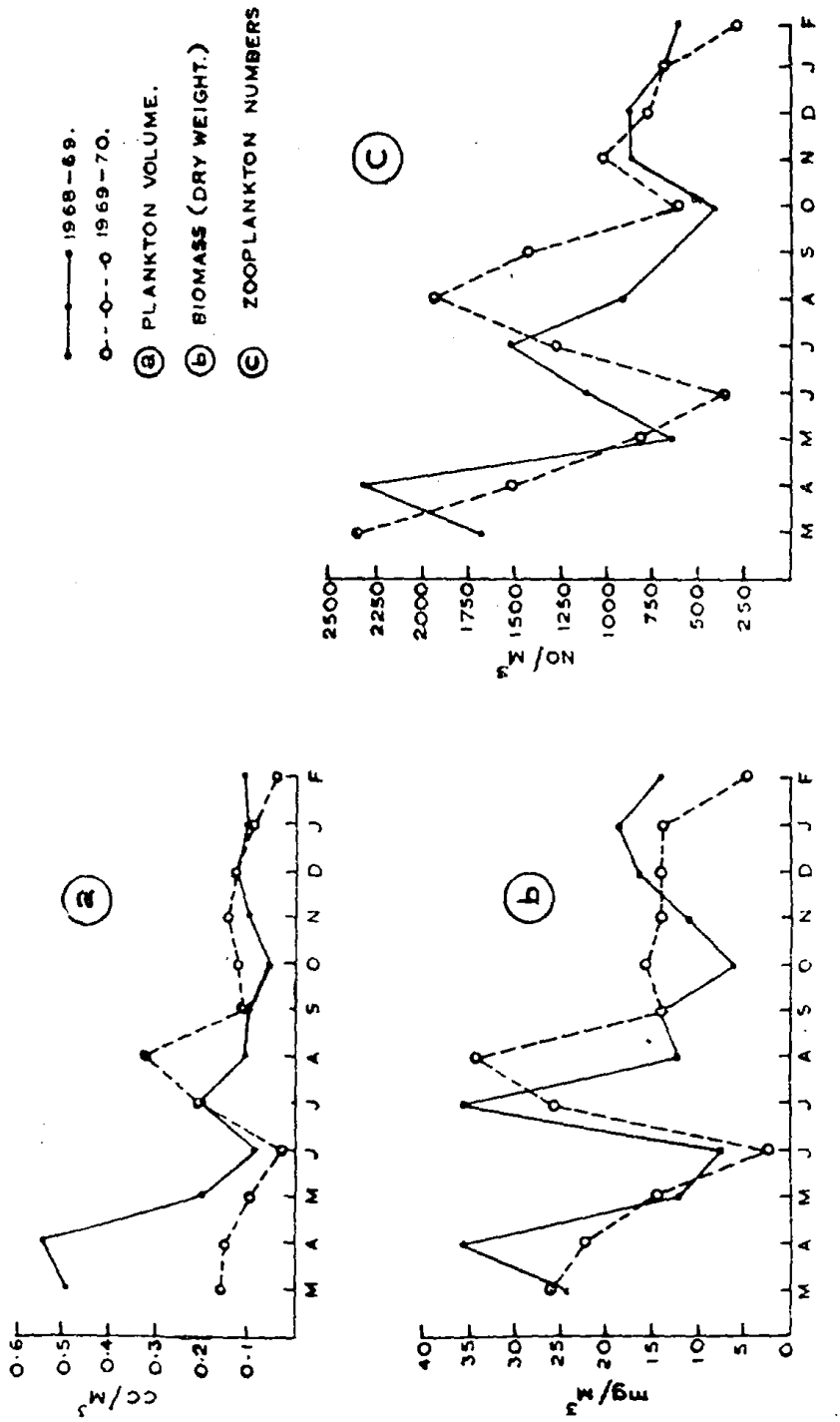

Fig. 4. Seasonal variation in the value of (a) Plankton Volume (b) Biomass (Dry weight), (c) Total Zooplankton Numbers.

Archipelago and the other entering the Bay of Bengal. The bottom Antarctic water enriches the Indian Equatorial waters entering the Bay during this period.

The hydrographical conditions such as salinity and temperature in the Bay are stable during the primary peak of phytoplankton production. It is interesting that large scale upwelling has been reported on the east coast during the months of March to May which also coincides with the season of high phytoplankton and zooplankton production.

A secondary peak of plankton production has also been observed in the August–October period when the hydrographical conditions in the Bay are unstable and when there is considerable dilution of the surface waters from the rivers which are full after the south-west monsoon (Fig. 3 & 4). The prevailing current during this period is in a southerly direction. This incidentally is also a period of turbulence owing to cyclonic weather conditions. According to Huntsman (1957) "Discharge of fresh water from rivers is of considerable importance, not in contributing nutrient salts but in making the deep water light when mixed with it and thus ensuring that it remains near the surface. The local productivity of plants in warm seas depends, in general, upon the rate of replacement in the surface water of the nutrient salts in short supply during the favourable season for growth." There is no doubt that large scale mixing of the low saline surface waters with the high saline nutrient rich bottom waters takes place during this period of turbulence which is conducive to rich phytoplankton production and which may account for the secondary peak.

Qualitatively there are two different and distinct populations of zooplankters in the two monsoon current periods. Figs. 5–7 illustrate the distribution patterns of three major components of the Zooplankton, namely, copepods, chaetognaths and siphonophores. This is largely true also of the other zooplanktonic organisms. The construction of the T–S–P diagrams is a handy tool to study the distribution pattern of planktonic organisms.

Conclusion

To sum up, the Bay of Bengal presents many unique meteorological and hydrological features which collectively account for its poor productivity in comparison with the Arabian Sea on the West Coast.

The constantly changing surface water masses from season to season having their own characteristic temperature, salinity and density are not conducive to large scale mixing, necessary for the transport of the nutrients to the surface euphotic zone from the deeper waters.

The large scale production of plankton is restricted to two periods; the primary peak coinciding with the season when the hydrographical conditions in the Bay are stable and incidentally this is also the period when there is

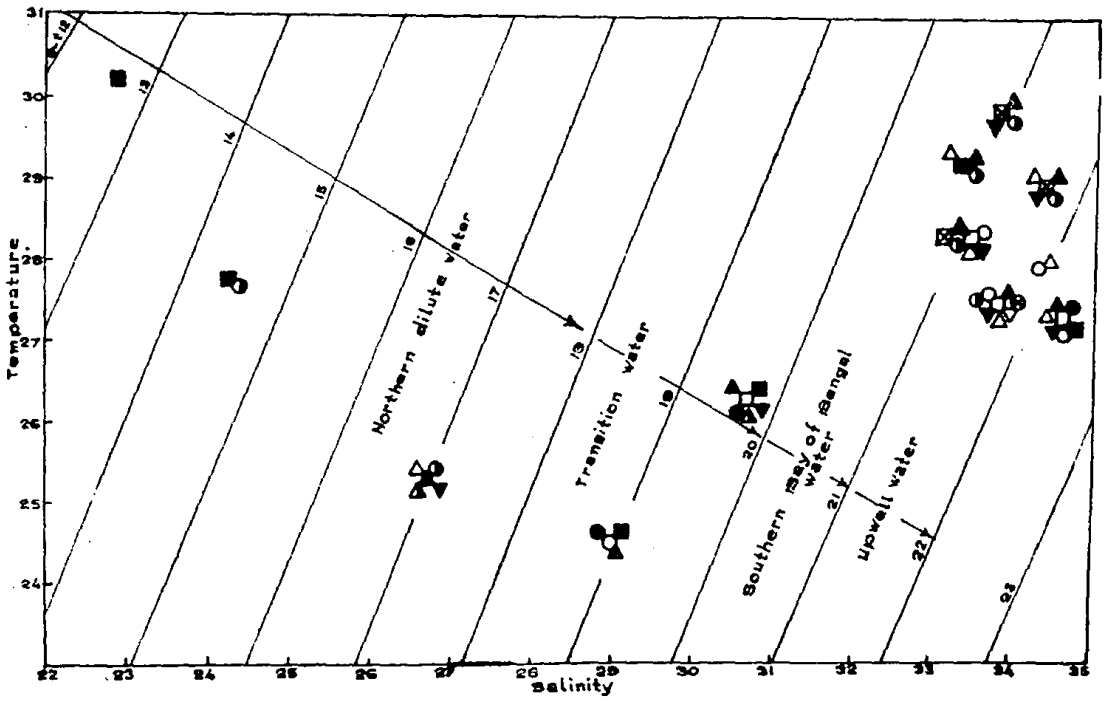

Fig 5. Showing the distribution of Copepods in relation to mean temperature and salinity

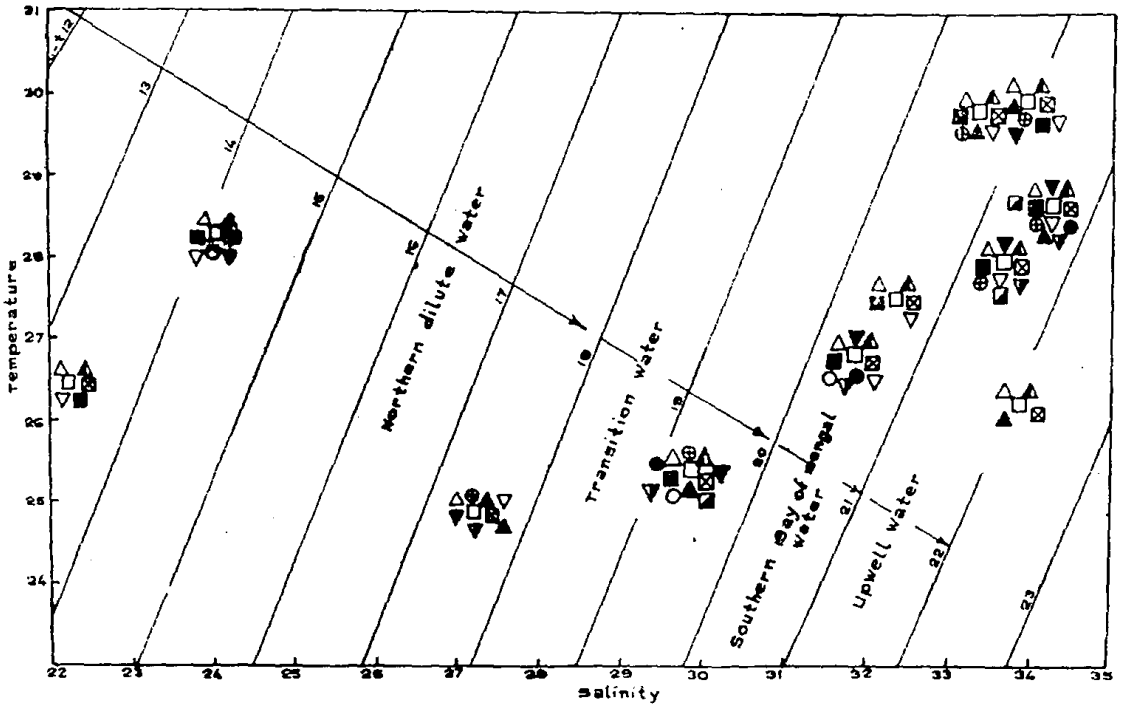

Fig 6 Showing the distribution of Chaetognatha in relation to mean temperature and salinity

Legend for Fig. 5

Symbol	Species
○	*Eucalanus attenuatus* *Eucalanus pseudoattenuatus*
□	*Eucalanus elongatus*
▽	*Rhincalanus cornutus* *Rhincalanus nasutus*
⊠	*Mecynocerà clausii*
■	*Euchaeta concinna*
⊖	*Euchaeta marina*
▼	*Euehaeta wolfendeni*
◐	*Lucicutia flavicornis*
⊛	*Copilia mirabilis*
⊠	*Corycaeus speciosus*
■	*Sapphirina nigromaculata*
●	*Sapphirina ovato-lanceolata*
▲	*Clytemnestra scutellata*

Legend for Fig. 6

Symbol	Species
□	*Sagitta enflata*
△	*Sagitta pulchra*
▲	*Sagitta neglecta*
■	*Sagitta tenuis*
▽	*Sagitta bedoti*
■	*Sagitta robusta*
⊕	*Sagitta regularis*
●	*Sagitta bipunctata*
○	*Sagitta hispida*
▲	*Sagitta serratodentata*
▼	*Pterosagitta draco*
◪	*Krohnitta subtilis*
▼	*Krohnitta pacifica*

large scale upwelling. The secondary peak coincides with the period when there is large scale mixing of the surface river water and the deeper nutrient rich bottom waters during periods of turbulence.

It is well known that rich plankton production in warm seas is limited to times and places where turbulence suffices to break down the thermocline and enrich the upper levels of the euphotic zone with nutrients (Hart, 1957). This is largely true of the Bay of Bengal where rich plankton production takes place during periods of upwelling or turbulence caused by sudden meteorological changes like cyclones and other disturbing factors. As Fishery production is dependent on the production of plankton, the search for new plankton rich areas in the Bay of Bengal should be vigorously pursued by full scale oceanographic observations in repeated series. It is possible that the Bay of Bengal is not as barren as it is visualised to be and a rational exploration by modern methods may bring to light rich sea food resources in the Bay which remain at present unexploited.

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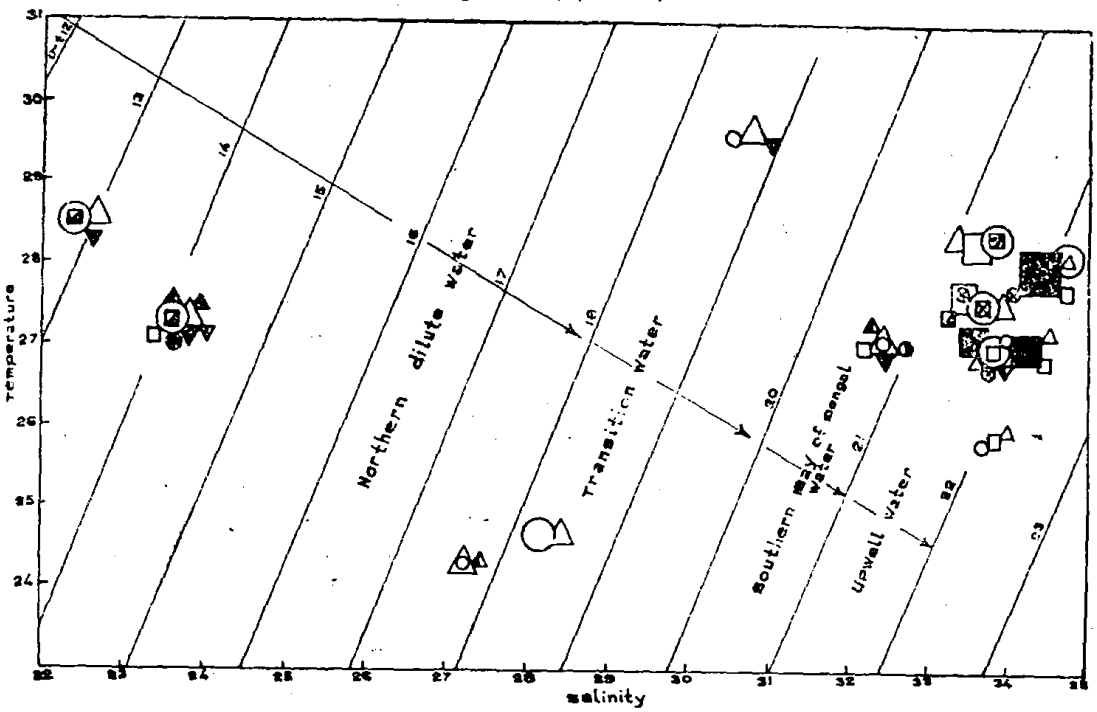

Fig. 7. Showing the disiribution of Siphonophora in relation to mean temperature and salinity.

Legend for Fig. 7

Symbol	Species
Δ	*Diphyes chamissonis*
□	*Diphyes dispar*
▼	*Diphyes bojani*
	Diphyes mitra
○	*Lensia Subtiloides*
◪	*Lensia campanella*
	Agalma elegans
◪	*Agalma okeni*
▽	*Sulculeolaria quadrivalvis*
⊗	*Sulculeolaria chuni*
▲	*Enneagonum hyalinum*
◐	*Abylopsis tetragona*
▽	*Abylopsis eschscholtzi*
▲	*Bassia bassensis*
▼	*Hippopodius hippopus*

Scale	Abundance (No/m^3)
—	0.1-1.0
——	1.1-4.0
——	4.1-8.0
——	8.1-12.0
——	12.1 >

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