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Species groups among pelagic tunicates in the western part of the Bay of Bengal

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Abstract

The tunicate species which frequently form part of each other's environment were assorted into groups by the use of an index derived from the corrected geometric mean of joint occurrence of pairs of species following Fager (1957) and Fager and McGowan (1963). The relationships shown in the temperature-salinity-plankton (TSP) diagrams between species and water properties are also used as a basis for classifying the species. Similar relationships have enabled species to be grouped together and consistent differences between one group and another set them apart.

Introduction

Oceanic zooplankton are small organisms spending most of their life suspended in water. Although the individual species inhabit large areas of the seas, most of them have well defined patterns of distribution and abundance. Plankton investigators often observe that certain species frequently occur together in the net hauls and that the species' composition of such groupings change from region to region and also from period to period. Until recently comments on the groupings have been made in the form of general statements or in the form of bar-diagrams (Fish, 1925; Sheard, 1949; Baker, 1954; Glover, 1957). Statistical methods based on presence or absence as proposed by Cole (1949) and Fager (1957) have been used by Fager and McGowan (1963), Sheard (1965) and Fager and Longhurst (1968). Methods based on abundance, using principal component analysis were employed by Williamson (1961) and Cassie (1963). Correlations between annual fluctuations of abundance of a single species in different areas was examined by Colebrook (1963). Methods based on presence and absence, abundance and predominance have also been used to analyse the distribution of benthic Amphipoda (Barnard, 1964). Various workers have tried methods for setting up "groups composed of species that have similar reactions to properties of the environment" (Fager and McGowan, 1963) to replace or supplement the use of a single species. The grouping procedure adopted in the present study is based on the lines followed by Fager (1957), Bary (1959, 1963, 1964), Fager and McGowan (1963), Sheard (1965) and Fager and Longhurst (1968).

Material and methods

The plankton samples collected from a fixed station at about 20 m in the waters off Visakhapatnam in Lawson's Bay, India, during 1956 to 1961 were analysed for pelagic tunicates. Plankton samples collected from about 750 stations in the western part of the Bay of Bengal during the first 52 oceanographic cruises conducted by the Andhra University during the years 1952 to 1957 were also analysed and the pelagic tunicates identified. The observations are based on samples collected during October to December (representing the south-westerly current period) and January to May (representing the north-easterly current period).

The horizontal plankton tows were made with a net 1.8 m long and 0.6 m in diameter made of fine bolting silk (with no flow-meter attached and with approximately 22 meshes per cm). A 500 ml capacity collector with a stop-cock was tied to the cod end of the net.

Information on the relative abundance of the pelagic tunicates is gained by employing rough numerical estimates (rare occurrence = 1—5, frequent = 5—20, and common = 20—100 per sample of roughly 500 ml).

The index of affinity originally used by Fager and McGowan (1963) is:

$$J/(N_A \cdot N_B)^{1/2} - 1/2\,(N_B)^{1/2} \qquad (1)$$

where

J = number of joint occurrences of paired species,
N_A = number of occurrences of species A,
N_B = number of occurrences of species B,
and
$N_A \leqslant N_B$.

This index varies from < 0 to 1.0. In the present study, the value of 0.50 was used as a break point. Pairs of species for which this expression was equal to or greater than 0.50 were considered to show affinity; those for which the values were lower were considered not to show affinity.

In constructing TSP diagrams (Bary, 1959), the occurrence of the species collected over an area is entered, using symbols, in the intercept of the mean temperature and salinity over brief periods. The rela-

tionships shown in the TSP diagrams between species and water properties are used as a basis for classifying the species. Similar relationships enable species to be grouped together and consistent differences between one group and another set them apart.

Hydrography of the area

The hydrographical conditions of the western part of the Bay of Bengal have been investigated by many previous workers (Sewell, 1929, 1932; La Fond, 1954, 1957, 1958a, b; Ganapati et al., 1956; Ganapati and Satyanarayana Rao, 1959; Banse, 1960). The annual range of temperature is about 25° to 29 °C. The temperature drops from about 27.5 °C during October to about 25.0 °C during December. This lowering of temperature is attributed to the general cooling of the atmosphere. There is an increase in temperature from about 25.0 °C during December to about 26.0 °C in January. The temperature further increases to about 27.0 °C by February. The increase in temperature is due to the reversal of the current direction from north-south to south-north bringing in warm oceanic waters from the equatorial region of the Indian Ocean. The upwelling of the deeper, cooler water takes place during the March to May period. However, the high values of temperature (about 27.5° to 28.5 °C) during this period suggest an overwhelming effect of summer heating throughout the upwelled waters.

The annual range of salinity is about 22 to 34‰. Low values of salinity are encountered during the October to November period. The decline in salinity is due to the strong south-westerly current bringing in large quantities of fresh water from north of the coast. The influx of fresh water subsides by December. The increase in salinity from about 28‰ during December to about 30‰ during January is due to an incursion of highly saline waters into the Bay from the equatorial region of the Indian Ocean. The salinity is high (about 34‰) during the March to May period; this is due to the upwelling of the highly saline, deeper waters.

During the October to November period, the surface water mass is the Northern Dilute Water (σt = less then 19). The water mass prevailing during the January to May period is largely the Southern Bay of Bengal Water (σt = 21—22). During the March to May period, the Upwelled Water (σt = 22—23) also comes up to the surface through pronounced upwelling of the deeper waters (La Fond, 1958b).

Seasonal distribution of pelagic tunicates

In the October to November period, *Oikopleura cophocerca*, *O. albicans*, *Megalocercus huxleyi*, *Fritillaria formica*, *Cyclosalpa pinnata*, *Brooksia rostrata*, *Ritteriella amboinensis*, *Pegea confoederata*, *Salpa fusiformis*, *S. maxima* and *S. cylindrica* were frequent or common. They were rare during the period from January to February. During March to April, coinciding with the period of intense upwelling, they were common.

Oikopleura rufescens, *Stegosoma magnum*, *Pelagopleura gracilis*, *Fritillaria haplostoma*, *F. abjornseni* and *Iasis zonaria* were rare during the October to November period, and were frequent or common during the period from January to May.

Oikopleura intermedia and *Fritillaria borealis* f. *sargassi* were recorded only during the January to May period. *Fritillaria pellucida* was recorded from March until May, and was common during this period. *Riteriella picteti* was recorded during October, November and March.

Species groups

The affinity information for the species is set out in a trellis diagram (Fig. 1). The species are relegated in terms of the number of other species with which they had affinity. In the present study this order is *A*, *B*, *C*... *T* and *U*. Starting with the species with the largest number of affinities, species are then counted in the direction of decreasing number of affinities until the number of species counted (X)

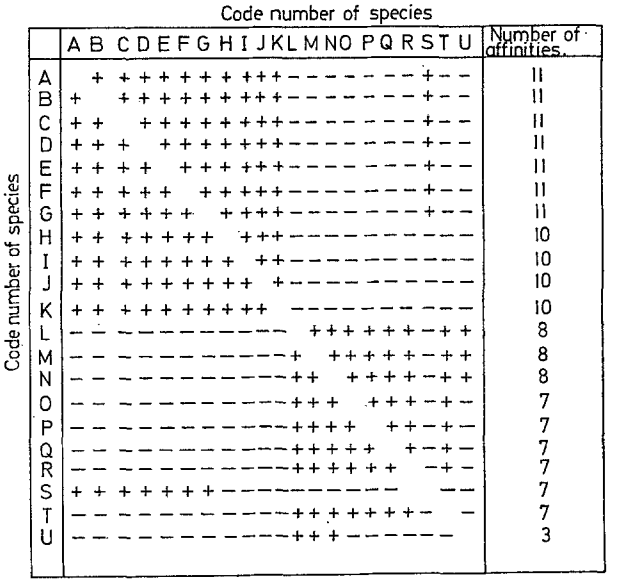


Fig. 1. Pelagic tunicates. Affinity between pairs of species. (Based on Fager and McGowan, 1963, index). +: Affinity (index $\geq$ 0.5); −: non-affinity (index < 0.5). *A Megalocercus huxleyi; B Fritillaria formica; C Cyclosalpa pinnata; D Oikopleura cophocerca; E Pegea confoederata; F Salpa maxima; G Oikopleura albicans; H Ritteriella amboinensis; I Salpa cylindrica; J S. fusiformis; K Brooksia rostrata; L Oikopleura rufescens; M Pelagopleura gracilis; N Fritillaria haplostoma; O Stegosoma magnum; P Fritillaria abjornseni; Q F. borealis* f. *sargassi; R Oikopleura intermedia; S Ritteriella picteti; T Iasis zonaria; U Fritillaria pellucida*

exceeds the number of affinities (Y) of the last species counted. In this instance this occurs at species K where $X = 11$ and $Y = 10$.

Two species groups are recognised in the western part of the Bay of Bengal. They are:

Group I including species from A to K, and

Group II including species from L to T.

Species which showed affinity with some, but not all, of the members of a group are considered as associates of the group (FAGER and LONGHURST, 1968). Accordingly, in the present instance, the species S is considered as an associate of the group including the species A to K and species U as an associate of the group which includes the species L to T.

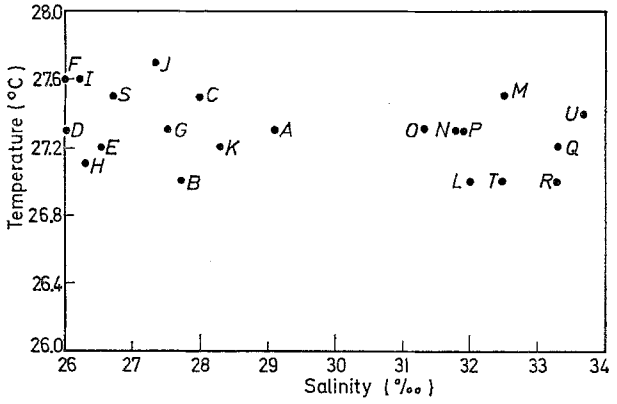
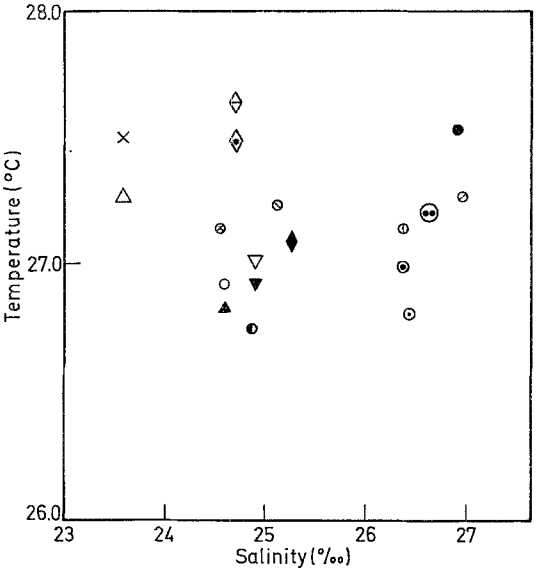


Fig. 2. Pelagic tunicates. Distribution in relation to mean temperature/salinity conditions during October/May. For lettering see legend to Fig. 1

The occurrence of the species collected from this area is entered, using symbols, in the intercept of the mean temperature and salinity. Similar relationships with the water body have enabled species to be grouped together, and consistent differences between one group and another have set them apart. The groups so formed divide into two series (Figs. 2, 3 and 4). They are:

(1) Group A (including species A to K and S) associated primarily with the temperature/salinity conditions similar to the Northern Dilute Water, and secondarily with those of the Southern Bay of Bengal and Upwelled Water masses.

(2) Group B (including species L to R, T and U) associated primarily with conditions similar to those of the Southern Bay of Bengal and Upwelled Water masses. Of these, L, M, N, O, P and T are secondarily associated with the Northern Dilute Water. They thus form a distinct group for themselves by virtue of their inhabiting the relatively more saline waters.



△ *Oikopleura cophocerca;*
▽ *O. albicans;*
◍ *O. rufescens;*
⊖ *O. intermedia;*
● *Fritillaria borealis f. sargassi;*
◐ *F. formica;*
⊕ *F. pellucida;*
⊙ *F. haplostoma;*
⊙ *F. abjornseni;*
◉ *Pelagopleura gracilis;*
● *Stegosoma magnum;*
▲ *Megalocercus huxleyi;*
▼ *Cyclosalpa pinnata;*
⊘ *Iasis zonaria;*
⊘ *Brooksia rostrata;*
○ *Ritteriella amboinensis;*
⊗ *R. picteti;*
◆ *Pegea confoederata;*
× *Salpa fusiformis;*
◈ *Salpa maxima;*
◈ *Salpa cylindrica.*

Fig. 3. Pelagic tunicates. Distribution in relation to mean temperature/salinity conditions during October/November

Remarks

Although the individual species inhabit large areas of the sea, most of them have a well defined pattern of distribution and abundance. Certain species frequently occur together in the net hauls. Pairs of species for which the index of affinity was equal to or greater than 0.50 were considered to show affinity, those for which the values were lower were considered not to show affinity. This break point was chosen as it

was felt that species should be found together in somewhat more than "half" their recorded occurrences if they are to be grouped together. This grouping procedure has led to the definition of the largest groups within which all possible pairs of species show affinity. All species within a group are, therefore, rather frequent members of each other's environment. Two species' groups among the pelagic tunicates occurring in the western part of the Bay of Bengal are presently recognised.

Salinity and temperature are factors having critical ranges for the lives of many species (Johnson and Brinton, 1963). In studies of the factors controlling the distribution of zooplankton species, there has been a tendency to regard the variables as acting separately and to find out the limiting factors among them. For instance, temperature acts as one control in the distribution of many species. Even in this case it has been shown (Berner and Reid, 1961) that the limitation can be a relative one. Attempts have recently been made in examining temperature and salinity acting together by Bary (1959, 1963, 1964) and Brinton (1962); temperature and light (Moore, 1952, 1955; Moore et al., 1953); and temperature, light and pressure (Moore and Corwin, 1956). These attempts have shown that the hydrographical factors act in combination, and in such a manner that the state of one modifies the limiting effect of another. The effect of temperature and that of salinity are considered in the present study. The TSP diagrams have demonstrated a close and consistent relationship between the species and the water bodies.

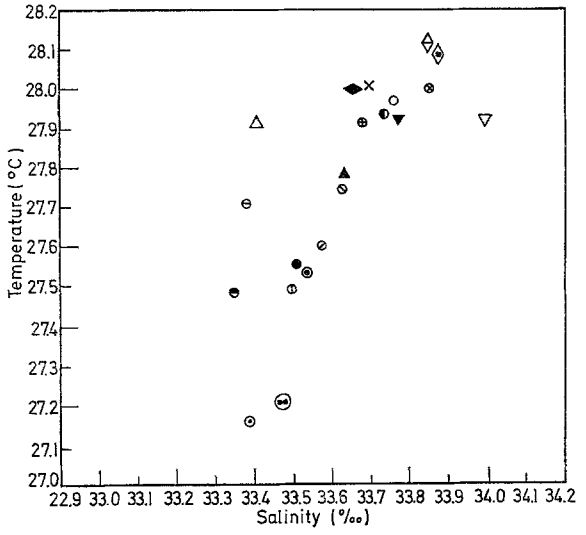


Fig. 4. Pelagic tunicates. Distribution in relation to mean temperature/salinity conditions during February/April. Symbols as in Fig. 3

Summary

1. The grouping procedure adopted in the present study is based on that followed by Fager (1957), Bary (1959, 1963, 1964), Fager and McGowan (1963), Sheard (1965) and Fager and Longhurst (1968).

2. Two species' groups among pelagic tunicates occurring in the western part of the Bay of Bengal are recognised. They are group *A* including *Megalocercus huxleyi*, *Fritillaria formica*, *Cyclosalpa pinnata*, *Oikopleura cophocerca*, *Pegea confoederata*, *Salpa maxima*, *Oikopleura albicans*, *Ritteriella amboinensis*, *Salpa cylindrica*, *S. fusiformis* and *Brooksia rostrata*, and group *B* including *Oikopleura rufescens*, *Pelagopleura gracilis*, *Fritillaria haplostoma*, *Stegosoma magnum*, *Fritillaria abjornseni*, *F. borealis* f. *sargassi*, *Oikopleura intermedia* and *Iasis zonaria*. *Ritteriella picteti* is considered as an associate of the first group, while *Fritillaria pellucida* is considered as an associate of the second group.

3. Similar relationships between the species and water properties have enabled species to be grouped together, and consistent differences between one group and another have set them apart.

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