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PATTERNS OF DISTRIBUTION OF ARABIAN SEA HYDROMEDUSAE*

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ABSTRACT

A comparison between the surface and subsurface waters of the Arabian Sea and those of Bay of Bengal from the hydromedusan fauna point of view shows the following similarities and differences: In both the seas there is a marked difference between surface and subsurface waters as compared to intermediate and deep waters. In both the seas the surface and subsurface waters are under the monsoonal regime with biannual fluctuations of the amount of incoming solar radiation, rate of evaporation, pattern of circulation, convection currents and upwelling. Both seas are very deep. In the Arabian sea, evaporation is greater than what the total influx of fresh water could compensate. In the Bay of Bengal, the influx of fresh water is greater than the evaporation due to the enormous amount of fresh water contributed by the Ganga-Brahmaputra system and by the Irrawaddi.

Surface and subsurface waters in the oceanic area of the Arabian Sea have high salinity and high temperature and come very close inshore, practically up to the coast line in many areas, while in the Bay of Bengal, biologically speaking, the situation is reversed, "coastal waters" with low and seasonally fluctuating salinity remain at the surface and carry with them the "coastal water" fauna of hydromedusae that are mainly meroplanktonic species. Towards the centre of the Bay of Bengal are generally found mainly long-lived meroplanktonic species like the Pandeidae and large Leptomedusae. No such species are found in the centre of the Arabian sea, while some occasional Laodiceidae are found on the eastern side, where salinity is lowest, specially in the surface layers, and where the extent of the shelf is greater.

The situation, however, is entirely different in intermediate and deep layers, where both the western (Arabian Sea) and eastern (Bay of Bengal) monsoonal areas of the Indian ocean are similar and are in biological communication with one another and also with the Central waters of the Indian Ocean, with the Antarctic Intermediate Water and with the Antarctic plankton in deep layers.

The biological and ecological factors that determine the structure of the community of hydromedusae, in addition to the prime factor, which is their exclusive carnivorous habits, give them a high place in the trophic web.

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INTRODUCTION

The hydromedusae are an interesting group for the study of the distribution of the plankton fauna, because they represent a homogeneous taxonomic group whose members are exclusively carnivorous throughout life. Furthermore, they are predators and kill their prey after capturing and paralysing it, with the poison contained in the nematocysts. Here we are concerned only with those species that have a planktonic stage throughout or during a part of their life history and therefore are members of the plankton community. They all have a gelatinous consistency and the diameter of the majority of the specimens is roughly between 200μ to 3000μ. Larger specimens of the large species are the Aequoridae (Leptomedusae), the Trachymedusae and a few Narcomedusae; these may reach a width of upto 5 cm, or rarely more, but are more frequently in the size range of approrimately 1-3 cm in diameter.

Because different species of hydromedusae have so may similarities, it is interesting to compare how the different details in their biology and ecology regulate the distribution and abundance of the species.

The biological and ecological factors that have been found to be decisive in determining the patters of distribution of this biologically speaking homogeneous group, are as follows: a) type of life cycle (whether holoplanktonic or meroplanktonic); b) type of reproduction (whether the medusa has or does not have vegetative reproductiion); c) longevity of the vagile phase (medusa); d) response to variation of environmental parameters of both the sessile phase (hydroid, when present) and the vagile phase (medusa, when present), i.e. the individuals adaptability; e) preferences for certain environmental factors.

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MATERIAL

This paper is a brief synopsis of the knowledge gained through the study of the hydromedusae contained in the plankton samples collected a) during the IIOE by the American ships; b) of the hydromedusae taken during the Antarctic programme sponsored by the National Science Foundation of the U. S. and c) of the series of samples taken by the Indian Ocean Biological Centre (IOBC) of the National Institute of Oceanography, India.

The research materials is represented by a) the hydromedusae sorted at the Smithsonian Oceanographic Sorting Centre (SOSC) in Washington, D.C. (U.S.), which were determined and counted by the authors at the Oceanographic Institute of the University of S. Paulo, Brazil; b) by the environmental data of the station at which the hydromedusae were taken as found in cruise reports of the participating institutions and in computer printouts of the World Oceanographic Data Centre A, in Washington, D.C. and c) the material and data collected and processed at the Indian Ocean Biological Centre (IOBC) by Santhakumari and Vannucci.

Papers by Navas (1971), Santhakumari and Vannucci (in press), Vannucci and Navas (1971, 1972), Vannucci and Santhakumari (1971) and Vannucci *et al.* (1970), contain detailed information on the species and their occurrence.

The present paper is neither an inventory nor a description of the fauna of hydromedusae and its distribution in the Arabian sea, but rather an abridged summary of the knowledge gained through years of study of this material.

The antarctic material of the Smithsonian Institution, being studied at present by Navas in S. Paulo, is not strictly comparable to the Indian Ocean material collected during the IIOE, because of differences in the nets used. Most of the antarctic material was collected with the IKMT (IsaacsKidd midwater trawl) that had a mesh width larger than that of the plankton nets used during the IIOE. Thus, only the larger sized species were collected in antarctic waters and so far we have no information on the smaller species and young stages of the larger antarctic and subantarctic species; nevertheless, the wealth of information contained in these samples makes them extremely interesting for comparison.

Ecological Distribution of Hydromedusae

The Arabian Sea environment

From the point of view of distribution of plankton species, the more important features of the Arabian sea are the following:

a) The water mass to be found from the surface to a depth of 100 to 150 m is Arabian sea surface water (ASSW) with salinity higher than 35.8‰ throughout its geographic range and higher than 36.5‰ in the western part.

Temperature is everywhere higher than 20 to 21°C, upto 30°C in the northern part in August. The dissolved oxygen content drops steadily below 50 m depth down to 1.13 ml/1. It is because of intense evaporation due to heating by solar radiation with relatively little fresh water input.

b) From 100 to 150 m depth down to 400 m, there is Arabian sea subsurface water (ASSSW). It has temperature from 10 to 19°C and salinity ranging from 35 to 36‰, higher towards the Red Sea and the Persian Gulf, with values upto 39.7‰, oxygen content is lower than 2 ml/l and falls very low or down to nil in the oxygen minimum layer. Anoxic conditions may occur mainly off the Indian coast and may at times reach the surface through process of upwelling or through upward tilting of the thermocline. It is formed by the input of the Red Sea and Persian Gulf waters, and is mixed by convection currents. Red Sea and Persian Gulf water may be traced down to 600 and 1000 m depth and as far south as Madagascar.

c) From 400 m depth down to about 1500 m, there is Arabian sea intermediate water (ASIW) with temperature ranging from 4 to 13°C and salinity between 35.0 and 35.5‰. At places where there is admixture of Red Sea water or Persian Gulf water, the salinity may be as high as 36.5‰; the dissolved oxygen content may vary from 0.4 to 1.43 ml/1. It is originated in the same manner as the ASSSW, but here convection plays no part.

d) At depths between 1500 and 3000 m there is Arabian sea deep water (ASDW) with temperature of 2°C or higher, salinity from 34.68 to 34.79‰ and about 3 ml/1 dissolved oxygen content. It results from the mixing of ASIW, south Indian Ocean intermediate water and Indian Ocean bottom water.

e) Depths greater than 3000 m are occupied by the Indian Ocean bottom water (IOBW) that results from mixing of antarctic bottom water and north Indian deep water. It is characterised by 0.2 to 1.47°C temperature, 34.69 to 34.77‰ salinity and 4.03 to 4.68 ml/1 dissolved oxygen content.

The Arabian sea may best be looked upon as the northwestern monsoon area of the Indian Ocean; it is under the influence of the monsoons, that cause a bi-annual reversal of the surface gyral with the associated phenomena of periodical upwellings specially intense during the SW monsoon in different areas; they also contribute to generating one of swiftest currents in the world, the seasonal Somali Current. Below surface layers, however, the water masses are not influenced directly by the monsoonal regime and are rather under direct or indirect influence of the antarctic system. The Arabian sea has two large embayments of oceanographic importance, the Persian Gulf that contributes a certain amount of dense, highly saline, high temperature water, through the Gulf of Oman and the Red Sea that contributes a considerable amount of high density, highly saline and hot water through the Gulf of Aden. Both Persian Gulf and Red Sea Water are formed locally by evaporation.

Biologically speaking, the Suez Canel has added a new dimension to the Indian Ocean and Arabian Sea in particular, by opening a passage way to species migrating to or, more rarely, from the Mediterranean. All the migrants must withstand the extreme conditions of salinity and temperature of the Great Bitter Lakes, either in an active or resting stage, in their crossing through the Suez Canal.

Finally, although many of the coastal areas bordering the Arabian sea have a high salinity and border hot, arid lands, there are also many estuaries and lagoons, with brackish waters or salinity gradients ranging from sea water to fresh water along the Indian coast. All, however, have high to very high temperatures. Finally, the upwelling areas on the western side of the Arabian sea are intense seasonal phenomena of biological importance towards determining the patterns of distribution and the abundance of species.

Distribution of the hydromedusae

In surface and subsurface waters and at their boundary, in the high seas far from land masses, the most abundant species are three Trachymedusae and one Narcomedusa that represent 70% or more of the total catch. All of them are holoplanktonic and are independent of the bottom for completing their life cycle. The species, in decreasing order of abundance are: *Aglaura hemistoma, Liriopa tetraphylla, Rhopalonema velatum* and *Solmundella bitentaculata*. Next in abundance, although much more rare, are the Narcomedusae *Pegantha martagon, Cunina octonaria, Panthachogon haeckeli,* (a Trachymedusa), *Cunina peregrina, C. frugifera* and *Pegantha triloba.* Many of the Narcomedusae of the genera *Cunina* and *Pegantha* have sessile larval stages, very small actinulae in their life cycles, but nevertheless they are independent of the bottom as a substratum, since the larvae when present live as commensals or parasites in the gastral cavity of other Narco—or Trachymedusae (rarely in Anthomedusae) and in *Tomopteris helgolandica* (Vannucci, unpublished). All of them are holoplanktonic and eurytopic for both salinity and temperature. Also the trachymedusa *Amphogona apicata,* that may also be found in ASSW and ASSSW, is found far from land masses and is eurytopic for both salinity and temperature.

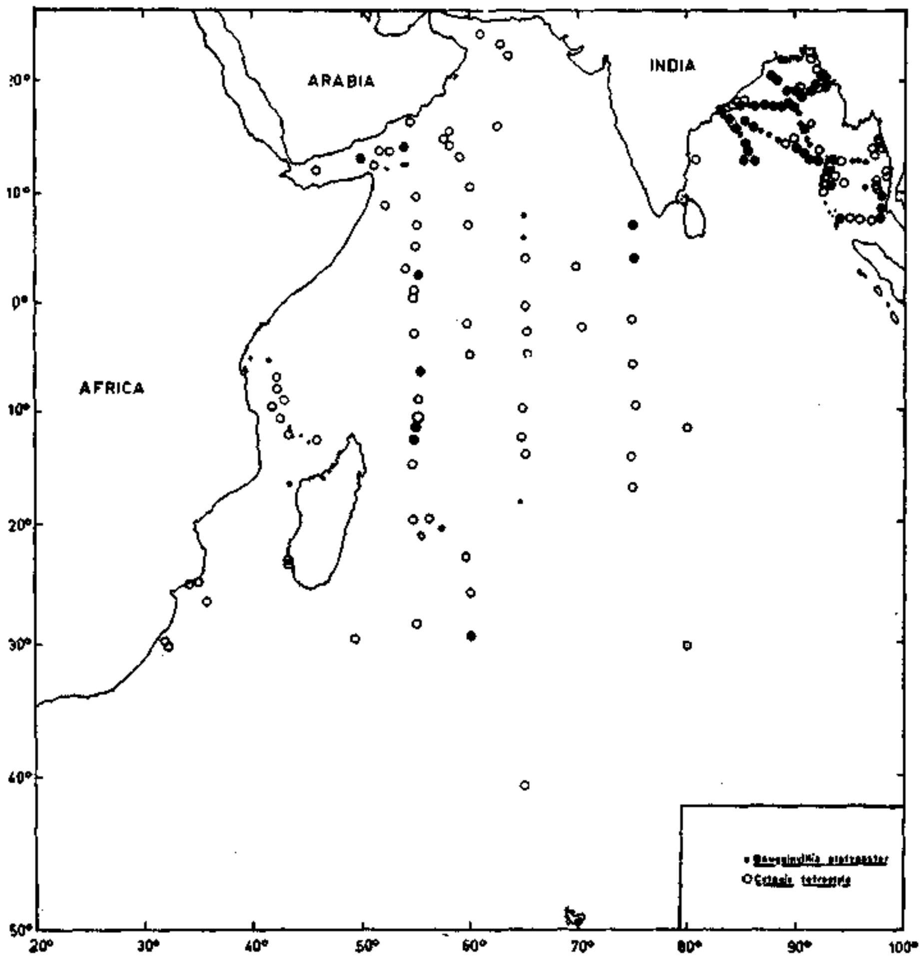


Fig. 1. Geographic distribution of *Cytaeis tetrastyla* and *Bougainvillia platygaster*. The overlap in distribution is relatively small.

The most frequent and abundant meroplanktonic species is *Cytaeis tetrastyla*, that is the fourth most abundant of all the species. It is an Anthomedusa that presumably may have a sessile hydroid stage in its life cycle but which normally multiplies through intensive vegetative reproduction of the medusa and thus becomes independent of the bottom to increase its numbers.

Bougainvillia platygaster is another Anthomedusa comparable to *C. tetrastyla* because it also has intensive vegetative reproduction of the medusa, and also most probably has a hydroid in its life cycle. They both have approximately the same size and are surface species (infrequently found in intermediate or deep waters), high temperature, eurythermal and euryhaline with high oxygen

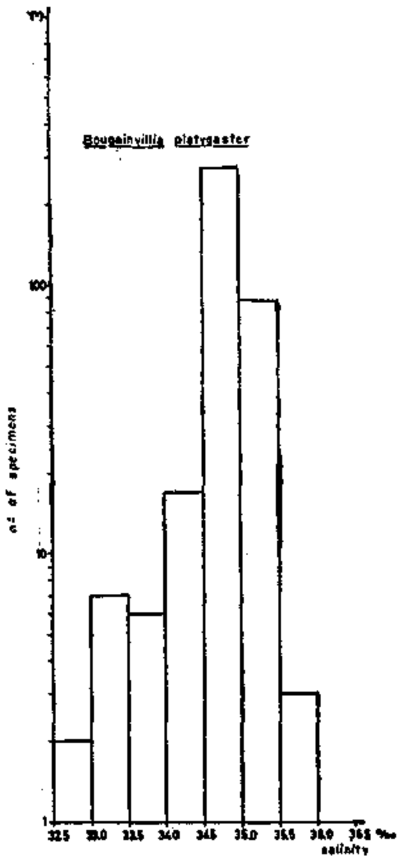


Fig. 2. Frequency distribution of *Bougainvillia platygaster* for salinity. A well marked mode is evident at the 34.5 to 35.0°/oo interval and virtual absence above 36.0°/oo.

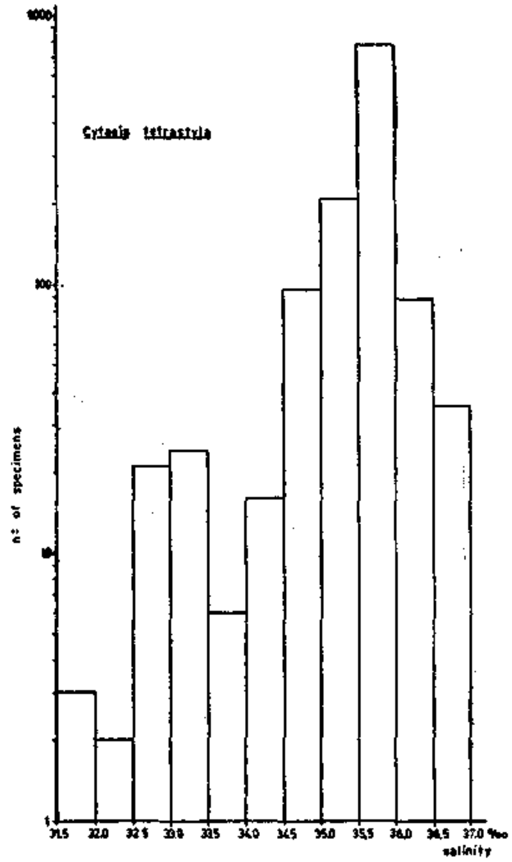
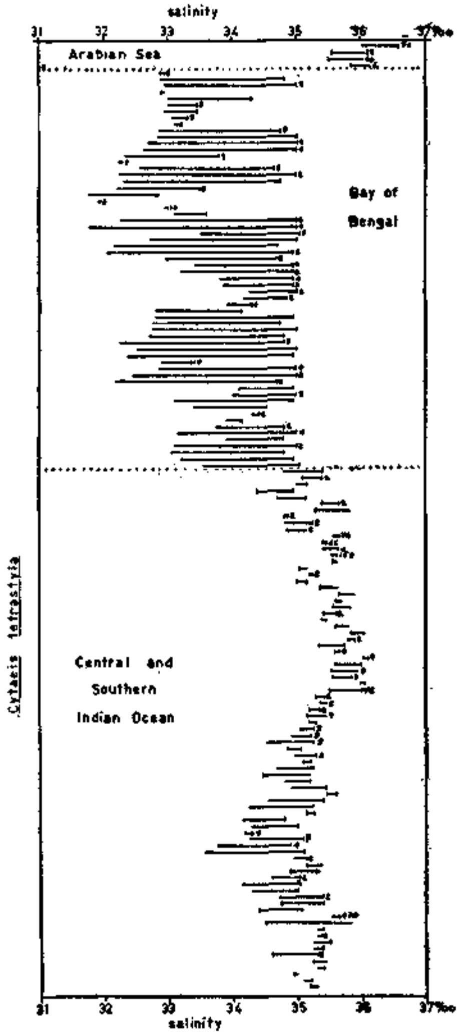


Fig. 3. Frequency distribution of *Cytaeis tetrastyla* for salinity. It was found on a wider range than *B. platygaster* with a mode at the 35.5 to 36.0°/oo interval.

requirements. Accordingly both have a wide geographic distribution. The salinity preferences of *B. platygaster*, however, are lower than those of *C. terastyla* (Figs. 2 and 3) and thus it is very frequent and abundant in the Bay of Bengal, while *C. tetrastyla* replaces it in frequency and abundance in the Arabian Sea (Fig. 1). The optima of *C. tetrastyla* appear to be around 35.5 to 35.6%o salinity, 17 to 21°C temperature and 5.3 to 5.5 ml/1 dissolved oxygen, while the optima for *B. platygaster* seem to be 34.5 to 35.5%o salinity, temperature higher than 23°C and high dissolved oxygen content (Figs. 4 and 5).



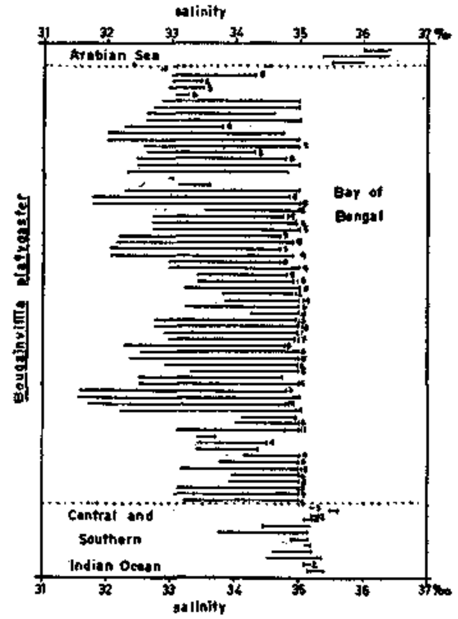


Fig. 5. Distribution of *Bougainvillia platygaster* in different water masses. Explanation of symbols as in Fig. 4. It shows that this species, differently from *C. tetrastyla* is to be found almost exclusively in the Bay of Bengal.

Fig. 4. Distribution of *Cytaeis tetrastyla* in different water masses. Salinity is show on abscissae. Each line corresponds to a haul and shows the salinity interval through which the net fished. The bar at the end of the line shows the maximum value that was reached, the open end indicates surface. When both ends are barred it indicates that a closing net was used, enclosing the salinity values shown. Numbers at the end of each line indicate the numbers of specimens caught; no number indicates that the sample had only one specimen.

No other species of hydromedusae were found to be well represented in ASSW, ASSSW and the boundary between the two, in the Arabian sea, away from the bordering coasts. Specimens of the other species were found occasionally and mostly they represent long-lived species, tolerant of high salinity. These are the Anthomedusae: *Heterotiara anonyma* and *Calycopsis papillata,* presumably they are both meroplanktonic; and another very long-lived Anthomedusa, *Koellikernia fasciculata,* that is a Mediterranean immigrant.

Summing up the hydromedusan fauna of the ASSW and ASSSW far from land is essentially made of Trachymedusae, then Narcomedusae and *Cyteais tetrastyla* (Anthomedusa with vegetative reproduction of the medusa) and other occasional species. High salinity, high temperature, distance from land and therefore a suitable substratum for the hydroids as well as an extensive oxygen poor layer are the most important environmental factors that act as a selective force for many species in these waters.

The hydromedusae of the Arabian Sea intermediate waters cannot be considered separate apart from the system of antarctic intermediate water (AIW). Although AIW as a water mass cannot be traced as such north of 10°S lat in the Indian Ocean (Wyrtki, 1971), the hydromedusae and, most probably, other plankton animals as well, have spread north and colonized the ASIW where conditions are comparable although temperature and salinity are higher and oxygen content may be lower than those of the AIW. Salinity of AIW is 34.2 to 34.8‰ (35.0 to 35.5‰ in ASIW), oxygen content ranges from 1.41 to 4.40 ml/1 (0.4 to 1.43 ml/1 in ASIW), and temperature about 4°C (4 to 13°C in ASIW). For these three parameters the equatorial intermediate water is in between AIW and ASIW and probably offer a passage for plankton species. Thus the medusae relatively abundant in the ASIW have also been found in AIW. They are all holoplanktonic Trachymedusae and Narcomedusae, with the exception of the long-lived Anthomedusa *Euphysora furcata.* They are the following species : *Botrynema brucei, Halicreas minimum, Solmissus marshalli, Aegina citrea, Aeginura grimaldi, Panthachogon haeckeli, Colobonema sericeum.*

Curiously enough, the deep sea widely distributed *Panthachogon haeckeli* and the antarctic congeneric species *P. scotti* have not been found in the intermediate layers of the Bay of Bengal, that are comparable to those of the Arabian Sea and support a similar fauna.

Furthermore, there are some AIW species that apparently do not enter in the Arabian Sea, for instance *Crossota brunnea,* a strict AIW water form which stops at lat. 10°S and is not to be seen in the Bay of Bengal either. Other antarctic species also were not recorded so far from the Arabian Sea.

There is a group of species that can be found in the lower range of ASSSW that were found only north of the subtropical convergence at 40°S lat. These are all holoplanktonic; *Sminthea eurygaster, Pegantha triloba* and *Amphogona apicata* that form a group of species distinct from the ASIW group of species. They are warmer water species and do not extend south of the subtropical convergence at 40°S lat; they belong to the Indian Ocean Central Water System. Some were found in the Bay of Bengal subsurface waters and AIW but not in the Arabian Sea.

The salient feature of the ASIW species is that they are essentially holoplanktonic, stenothermal and with high oxygen requirements.

We do not have sufficient information on the hydromedusae of the deep and bottom waters of the Arabian Sea.

What precedes refers to the hydromedusae of the open ocean in the Arabian Sea. The distribution and abundance of the neritic fauna are more difficult to describe on a general basis, because of the varied conditions of the peripheral areas of the Arabian Sea. Furthermore, we do not have samples from the Persian Gulf nor from the Red Sea and only a few from the Gulf of Oman and from the Gulf of Aden. Red Sea samples taken by the "Meteor" during the IIOE are being studied by Eckardt-Schmidt.

In a general way, however, in near shore waters there is a reversal in relative abundance, with increase of meroplanktonic forms, and decrease of holoplanktonic species. In neritic waters of the western side of the Arabian Sea. the selective factors of major importance are temperature and salinity and a holoplanktonic life cycle is not the selective factor of much importance. Only those species that tolerate or prefer higher ranges of both these parameters are present, along with high salinity and high temperature holoplanktonic species like *Cunina peregrina, C. octonaria* and *C. frugifera*. Some holoplanktonic species may also be found in the western Arabian Sea, such are *Solmissus marshalli, Panthachogon haeckeli, P. scotti, pegantha clara, P. triloba, P. martagon* and *Amphogona apicata*. These species are eurytopic to a large extent, for both temperature and salinity, excepting *Panthachogon scotti* which was taken in temperature not higher than 14.5°C and about 35.5%o salinity.

They are mainly found at Shallower depths only in regions of intensive upwelling, such as along the Arabian Peninsula.

Other holoplanktonic forms were captured near the coast, but in subsurface or intermediate (ASSSW or in ASIW) waters only. These are: *Sminthea eurygaster, Aegina citrea, Halicreas minimum, Colobonema sericeum*. The meroplanktonic species which were more abundant in the western and northern Arabian Sea were: *Eirene viridula* (rare), *Bougainvillia fulva, Aequorea aequorea, A. pensilis, Heterotiara minor, H. anonyma, Laodicea fijiana, Vannuccia* *forbesi, Zanclea orientalis, Z. costala, Euphysora bigelowi.* In no place they were as abundant as the holoplanktonic off shore medusae, and most of them were concentrated in the Gulf of Aden, where total zooplankton volume per unit of water was among the highest from the Arabian sea.

We have no knowledge of the hydromedusae of special environments along the coast of western Arabian sea.

The eastern Arabian sea is entirely different from the western side. But not much is known of the hydromedusae of the coasts of Pakistan and India and most of our knowledge centres on samples taken in the bays of Goa and in the backwaters of Kerala. These are strongly dominated by meroplanktonic medusae although some of the eurytopic holoplanktonic species may be found frequently and sometimes in swarms such a *Liriope tetraphylla,* quite near the shore. The rather rare Trachymedusa *Petasiella asymmetrica* may perhaps occur with relative abundance (Vannucci and Santhakumari, 1971).

The influx of fresh water from land into the Arabian sea apart from the water contributed by the Indus river, does not extend far out into the sea, except in the surface layer and at specific places and seasons, where warm low density water may be found for miles in the sea as a thin layer mainly during and after the SW monsoon. Thus everywhere in the Arabian sea, (Ramamirtham and Jayaraman, 1963), high salinity and high temperature waters come very close inshore and also along the eastern side of the Arabian sea. These carry with them holoplanktonic species that are often brought to relatively shallow depths during the upwelling.

The major mass of meroplanktonic fauna of hydromedusae is to be found in estuaries, embayments and backwaters. These show the typical association of species of such environments, for they are euryhaline, warm water forms and tolerant of abrupt and sometimes drastic environmental changes. They are the same species as found all over the tropical belt in such environments and are often present in swarms (density of up to 50 specimens/m^3). Such are: *Blackfordia virginica* and its sibling species *Phialucium carolinae,* species of the Eirenidae, Eutimidae and Lovenellidae.

To sum up, it seems that the coastal, estuarine and backwaters of the Arbian sea are characterized by the usual association of meroplanktonic euryhaline warm species as are found under such conditions in all the tropical belt. They are also characterized by their occurrence along the coast line, at places where the shelf is very narrow, or at times or upwelling. Thus *Cytaeis tetrastyla,* Rhoppalonematidae, Geryonidae and Cuninidae are found very near the shore. This is due to the peculiar conditions of very high temperature and salinity of the Arbian sea waters that come to the edge of the land even when dilution occurs at the surface due to rains or runoff from land. As in other tropical, subtropical and temperate areas, certain species of the Aequoridae are found at the boundary area between marine and brackish water species.

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