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A PRELIMINARY REPORT ON THE DISTRIBUTION AND RELATIVE ABUNDANCE OF EUTHECOSOMATA WITH A NOTE ON THE SEASONAL VARIATION OF *LIMACINA* SPECIES IN THE INDIAN OCEAN

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Euthecosomata (holoplanktonic opisthobranch molluscs) sorted out from the collections of the International Indian Ocean Expedition are now being studied and the present communication is a first report based on an examination of material from 395 stations. Species were identified with the help of Tesch's studies (1946, 48) on the Dana Collections. *Limacina helicina* (Phipps) is newly recorded from the Indian Ocean. Including it, twenty-five species of euthecosomes are known to occur in this Ocean. This paper reports on twenty species, their distribution and numerical abundance over the Indian Ocean and compares present results with earlier records of the group in the Indian Ocean. The occurrence of a greater number of species as well as of larger numbers of individuals of particular species, is noted from the following areas: the sea east of Somalia, the Mozambique channel, the equatorial belt of the Indian Ocean, specified areas of the Arabian sea and Bay of Bengal. The most noteworthy of these areas is to the east of Somalia from where consistently high numbers of individuals were obtained for a good many species. This area is well-known for the upwelling of nutrient rich water during the south-west monsoon period and for its high biological productivity. A comparison of different months of the year with respect to the numerical abundance of three species of *Limacina*, indicated that all three species were at maximum abundance during August, which is the peak period of the south-west monsoon. Some species, e.g., *Styliola subula*, *Cuvierina columnella*, *Cavolinia globulosa* and *C. inflexa*, that are common in the equatorial belt and in Somali waters, are rare in the Bay of Bengal and the Arabian Sea, but the reasons for this are yet to be unravelled.

INTRODUCTION

Our present knowledge of the Thecosomata (formerly known as Pteropods) is based on the reports of the several expeditions carried out during the last hundred years. However, owing to the lack of intensive and systematic sampling, information on the pattern of distribution and relative abundance of these holoplanktonic forms in the Indian Ocean is incomplete. The available records are from the expeditions listed in Table I.

TABLE I

Name of the Expedition	Author of report	No. of species of euthecosomes recorded in the Indian Ocean
Voyage of H.M.S. Challenger (1873-76)	Pelseneer, P. (1888)	20
Deut. Tiefsee Expedition 'Valdivia' (1898-1899)	Meisenheimer, J. (1905)	21
John Murray Expedition (1933-34)	Stubbings, H.G. (1937)	16
Percy Sladen Trust Expedition (1905)	Tesch, J. J. (1910)	18
'Dana' (Indo-Pacific 1928-1930)	Tesch, J. J. (1948)	21
'Umitaka Maru' Expedition (Indo-Pacific 1956)	Taki, I. & Okutani, T. (1962)	16

The present report is based on an examination of Euthecosomata sorted out from 395 zooplankton samples collected by R.V. *Argo* and R.V. *Anton Bruun* during the International Indian Ocean Expedition. The areas explored by these two ships are the Arabian Sea, the Bay of Bengal, the equatorial zone and the south-western part of the Indian Ocean, to 80° E and 45° S. The positions of the stations of Cruises I to VIII of *Anton Bruun* and of the "Lusiad" and "Dodo" cruises of *Argo* are shown in figure 1 together with the distribution of *Limacina inflata*. No collections have been examined from the west coast of India, west coast of Sumatra and the south-eastern part of the Indian Ocean. The report is preliminary in that it includes data based on about a fifth of the samples in the international collections at the Indian Ocean Biological Centre. The Order Thecosomata includes two suborders, Euthecosomata and Pseudothechosomata. The present report deals only with the Euthecosomata, as the identification of the Pseudothechosomata has not yet been completed. McGowan (1960) states that there are 35 species of Euthecosomata recognized. Of these, 24 have so far been recorded from the Indian Ocean by previous expeditions. With a new record of *L. helicina*, the number of recorded species now increases to 25. Of the 25, not less than 20 have been found in the present collections. The attempt to relate distribution with hydrographical factors is done tentatively owing to the limited information available.

REVIEW OF DISTRIBUTION OF SPECIES

Systematic List of Species

Family Limacinidae Gray 1847.

Genus *Limacina* (Cuvier) Lamarck 1819.

1. *L. inflata* (d'Orbigny 1836)
2. *L. bullimoides* (d'Orbigny 1836)
3. *L. trochiformis* (d'Orbigny 1836)
4. *L. lesueuri* (d'Orbigny 1836)
5. *L. helicina* (Phipps 1774)

Family Cavoliniidae (d'Orbigny 1841)

Genus *Clio* Linne' 1767

6. *C. pyramidata* Linne' 1767
7. *C. cuspidata* (Bosc 1802)
8. *C. balantium* (Rang 1834)

Genus *Creseis* Rang 1828

9. *C. virgula* Rang 1828
10. *C. acicula* Rang 1828

Genus *Styliola* Lesueur 1810

11. *S. subula* Quoy and Gaimard 1827

Genus *Hyalocylix* Fol 1875

12. *H. striata* (Rang 1828)

Genus *Cuvierina* Boas 1886

13. *C. columnella* (Rang 1827)

Genus *Diacria* Gray 1850

14. *D. quadridentata* (Lesueur 1821)
15. *D. trispinosa* (Lesueur 1821)

Genus *Cavolinia* Abilgaard 1791

16. *C. longirostris* (Lesueur 1821)
17. *C. globulosa* (Rang 1850)
18. *C. inflexa* (Lesueur 1813)
19. *C. uncinata* (Rang 1836)
20. *C. gibbosa* (Rang 1836)

Limacina inflata (d'Orbigny)

The distribution of this species (Fig. 1) is not uniform over the area of occurrence, but it does extend over a wide area with localized regions of greater abundance. Such areas are, except for one station, between 20° N and 20° S. They lie mainly off the coasts of equatorial Africa and Arabia, between 5° S and 10° N, 45° E and 55° E. According to McGowan (1960) in the Pacific "this species is responding to an 'enrichment' of its environment due to the upward mixing of nutrient rich deepwater in the equatorial current system...." This explanation seems also to be true in the present instance, since the areas of maximum abundance noticed here are regions associated with well-known centres of upwelling off the Somali and Arabian coasts during the period of the south-west monsoon. In the southern part of the Indian Ocean between 20° S and 40° S, 55° E and 80° E, where the hydrographic conditions are comparatively stable, the population density is low, a feature in which the present observation agrees well with what McGowan has noticed in the part of the eastern tropical Pacific in zone 10° - 20° N.

Limacina bulimoides (d'Orbigny)

The general pattern of distribution of this species resembles that of *L. inflata*, but occurrences are scarcer south of 30° S (Fig. 2). Maximum concentrations are between 10° S and 12° N, but mainly east of Somalia. This area is more restricted than the area of *L. inflata* maximum, suggesting an even closer tie with the upwelling-enriched conditions off Somalia where the temperature is low during June-September.

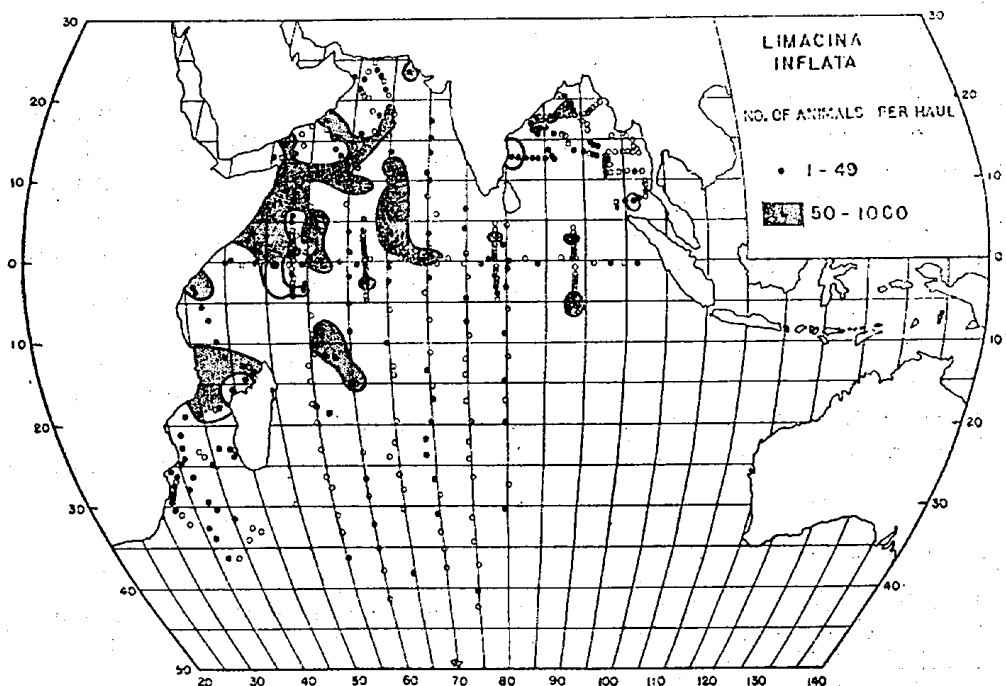


FIG. 1. The distribution of *Limacina inflata*.

Limacina trochiformis (d'Orbigny)

Unlike the reported distribution in the Pacific and Atlantic, *L. trochiformis* is a common and widespread species in the Indian Ocean (Fig. 3). But the area of maximum concentration is smaller than that of the two *Limacina* species discussed above. The high abundance of this species is similar to the other two species seen off the Somali coast between 0° and 10° N, 45° E and 55° E.

SEASONAL VARIATION IN *Limacina inflata*, *L. bulimoides* AND *L. trochiformis*

The above three species of *Limacina* showed seasonal changes in abundance (Fig. 4). Monthly values of population-density were calculated for each species for the period 1962-1964. These values represent the average number of specimens per standard sample, based on all samples containing positive records (Figs. 1-3). The period of December (no samples) and January (three samples) was poorly represented in the material examined, whereas April-May and July-October were well represented (22-47 samples per month). It can be seen that the three species have somewhat independent patterns of fluctuation during January-May, when populations are small. In June a decline is discernible, followed by an abrupt tenfold increase in July and August. After the August peak, there is a decline until November. The area of maximum population-density for all three *Limacina* species has been noted to be off the Somali coast. The strong correlation between season and abundance of the species is probably related to enrichment of that region by means of intensive upwelling during the south-west monsoon, June-September.

Limacina lesueuri (d'Orbigny)

Out of 395 samples examined, only 17 contained this species. On this basis it is considered rare in the Indian Ocean. From the nature of the distribution (Fig. 5) it is evident that all records except one are from south of the equator. There is no previous or present record of this species from the Arabian Sea, an area characterized by low oxygen concentration at intermediate depths one ml/l at 150 m, and high salinities 34-36.5‰ (Nejman 1961). It is interesting to note its most frequent presence in the Mozambique Channel and to the east of South Africa.

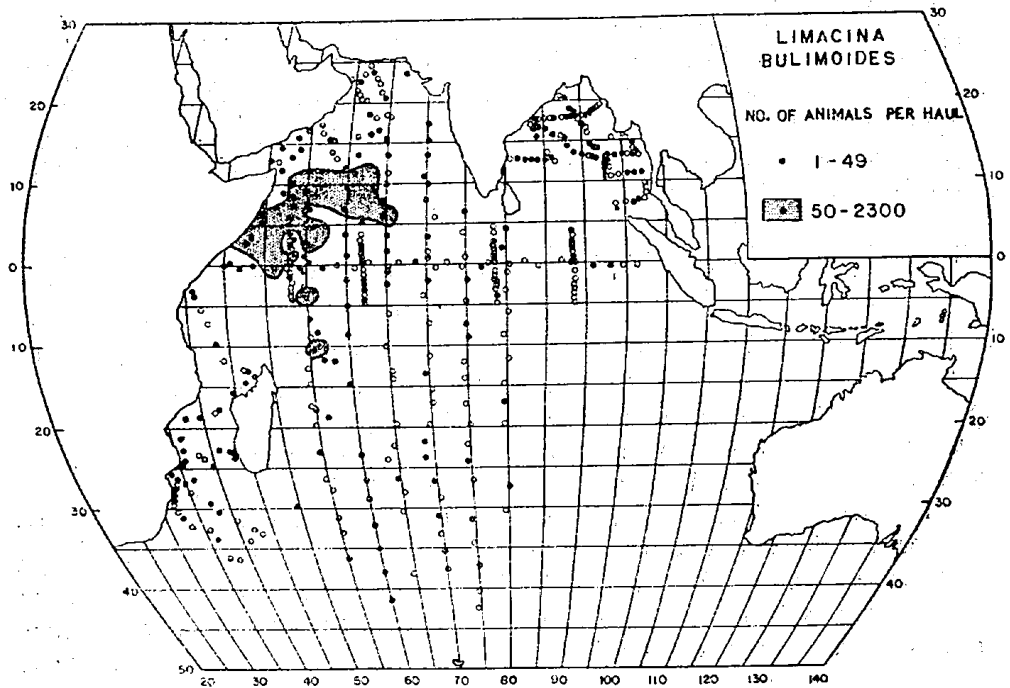
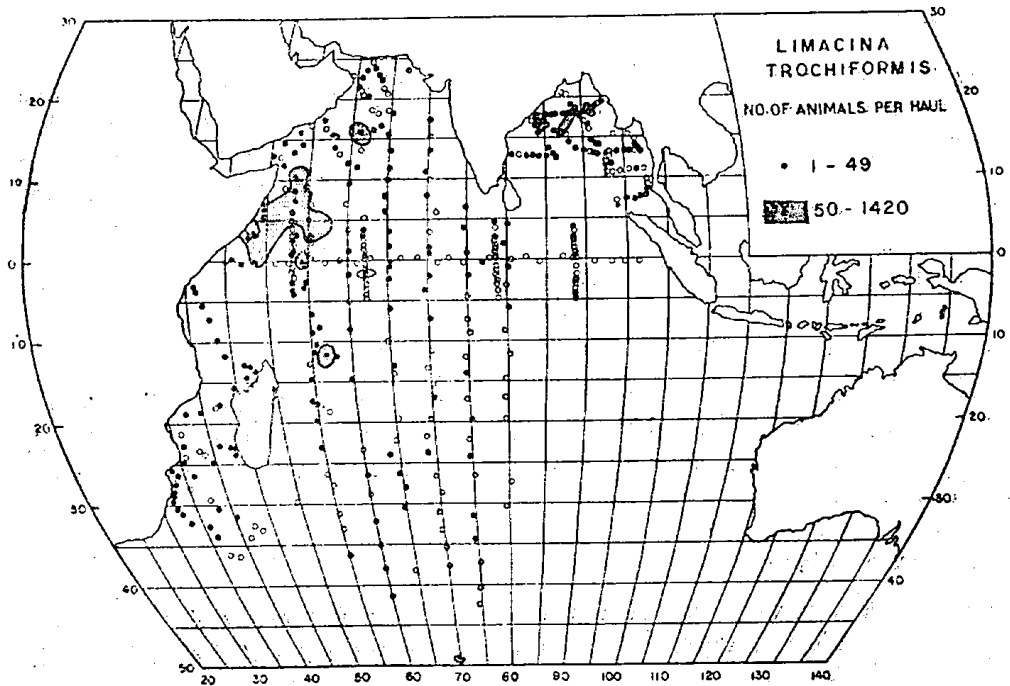
Limacina helicina (Phipps)

This is a cold water species not hitherto recorded from the Indian Ocean. There are only three records (Fig. 5), two of which are off Durban and one at 35° S, 60° E. These occurrences are clearly related to the temperate environment in the zone of 25-35° S.

Clio pyramidata Linne'*

According to Tesch (1948) this cosmopolitan species is eurythermic to a certain degree. In the North Atlantic it is known to penetrate regularly beyond 40° N.

*The variants of *Clio pyramidata* have not been identified yet consequent on the absence of the shell in most of the specimens.

FIG. 2. The distribution of *Limacina bulimoides*.FIG. 3. The distribution of *Limacina trochiformis*;

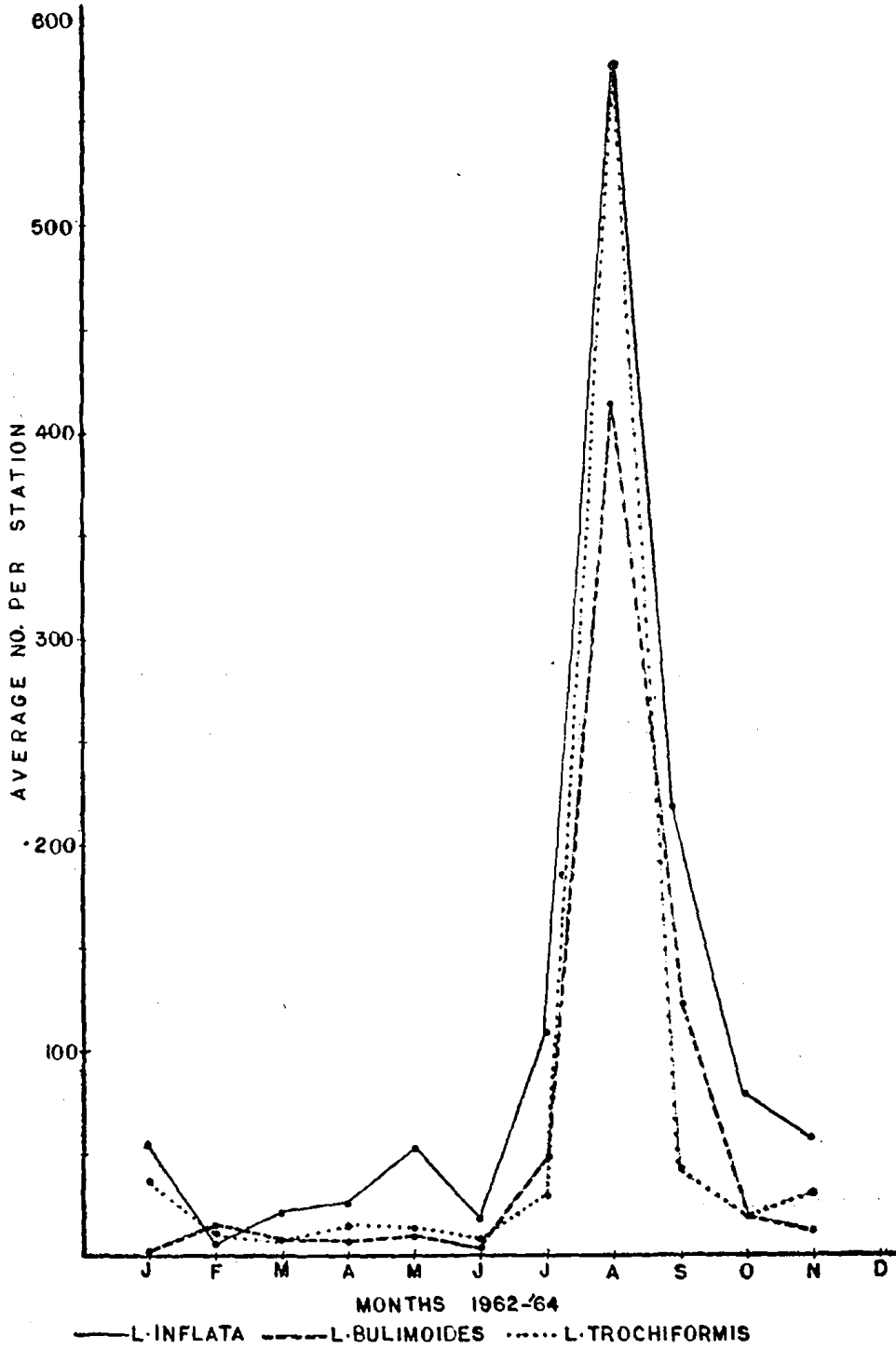


FIG. 4. Seasonal variation in *L. inflata*, *L. bulimoides*, *L. trochiformis*.

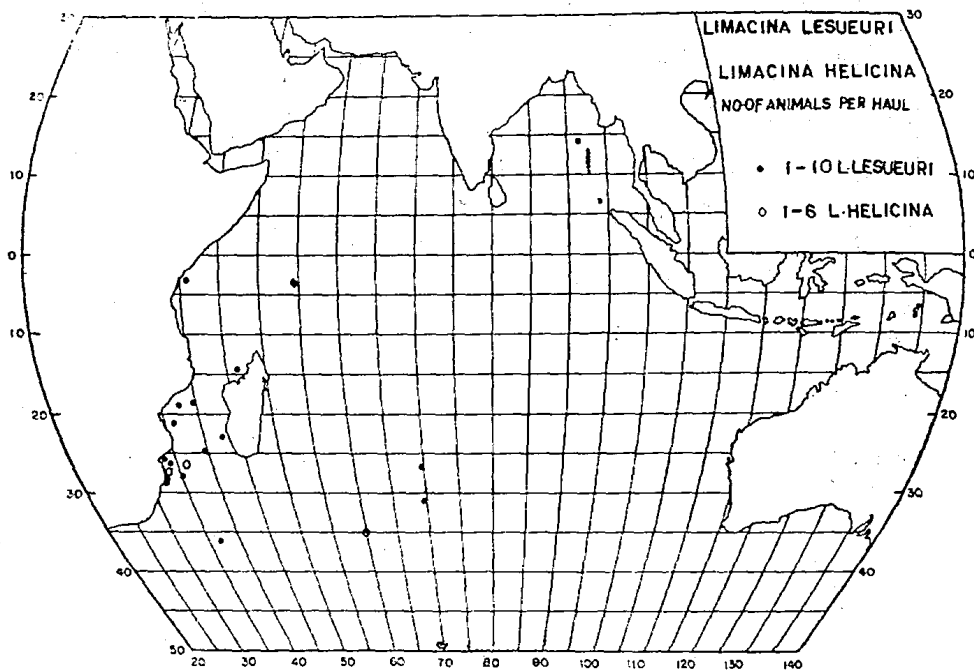


FIG. 5. The distribution of *Limacina lesueuri* and *L. helicina*.

"At the east coast of Africa it reaches, in isolated individuals, less than 50 specimens per hour's fishing, down to the latitude of Durban".

In the Indian Ocean this widespread species is apparently most common off the Somali coast, in the western equatorial Indian Ocean, the Bay of Bengal and northern Arabian Sea (Fig. 6).

Clio cuspidata (Bosc)

The rarity of the species in the present material is clear from the fact that there are only two records of adult specimens: $02^{\circ} 00'S$, $62^{\circ} 20'E$ and $03^{\circ} 34'S$, $40^{\circ} 53'E$. Tesch (1948) however, found this to be a common species in the Indian Ocean. The rarity of *C. cuspidata* in the present samples may be due to the fact that juveniles have not yet been identified. McGowan (1960) attributed the rare occurrence of this species to an extreme form of patchiness in its distribution.

Clio balantium (Rang)

There are only five previous records in the Indian Ocean (Meisenheimer 1905; Tesch 1948) of which three are south-east and south of Madagascar, one south of Ceylon and the other off the west coast of Sumatra. All three of the present records are from the Bay of Bengal $18^{\circ} 33'N$, $91^{\circ} 16'E$, $12^{\circ} 56'N$, $92^{\circ} 10'E$; $14^{\circ} 15'N$, $91^{\circ} 50'E$. Because of imperfect preservation and consequent distortion

and damage, the identification is tentative. However, the broadly developed fins and the conspicuous posterior foot lobe indicate a close resemblance to *C. balantium*.

Creseis virgula Rang*

The scattered but widespread occurrences of this species are more consistent along the equatorial zone, off the Somali coast, the Bay of Bengal, and the Gulf of Oman (Fig. 7). All of the samples containing more than 50 specimens are from north of 10° S suggesting that this is mainly a tropical species. Occurrences south of 20° S are few. Tesch (1948) has also remarked on the wide occurrence of this species in the tropical Indo-Pacific.

Creseis acicula Rang

This species is of very general occurrence in the Arabian Sea, the Bay of Bengal, the western equatorial Indian Ocean and the Mozambique Channel (Fig. 8). High concentrations at a few stations off south-east Africa may be related to the influence of the land mass, as this species is recognized as being often abundant close to the shore in shallow bays and inlets. The southernmost occurrence was noted at 32° S.

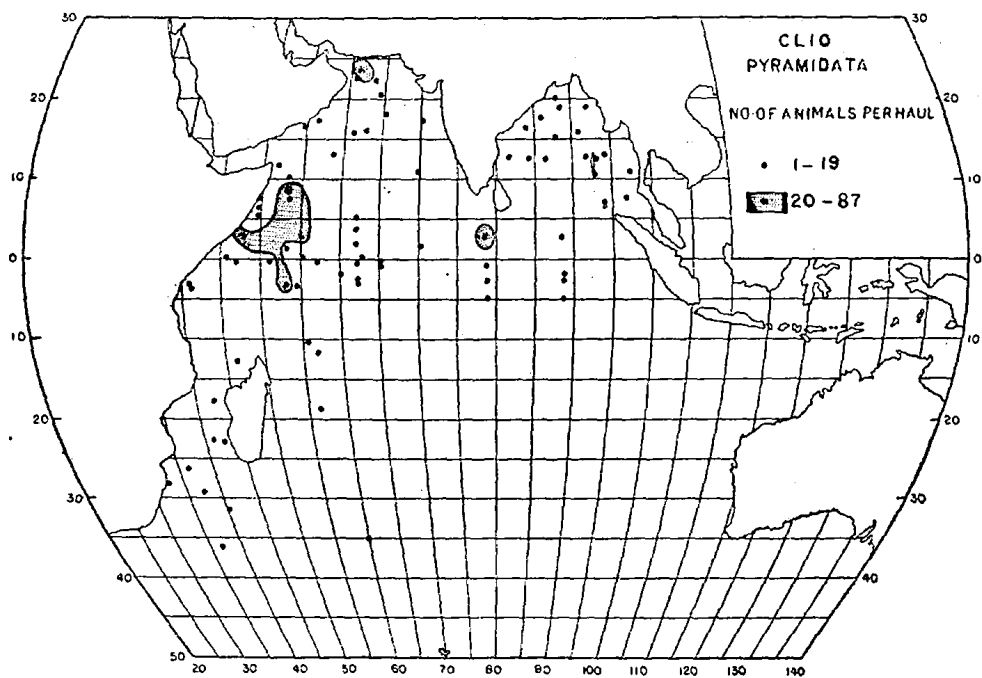
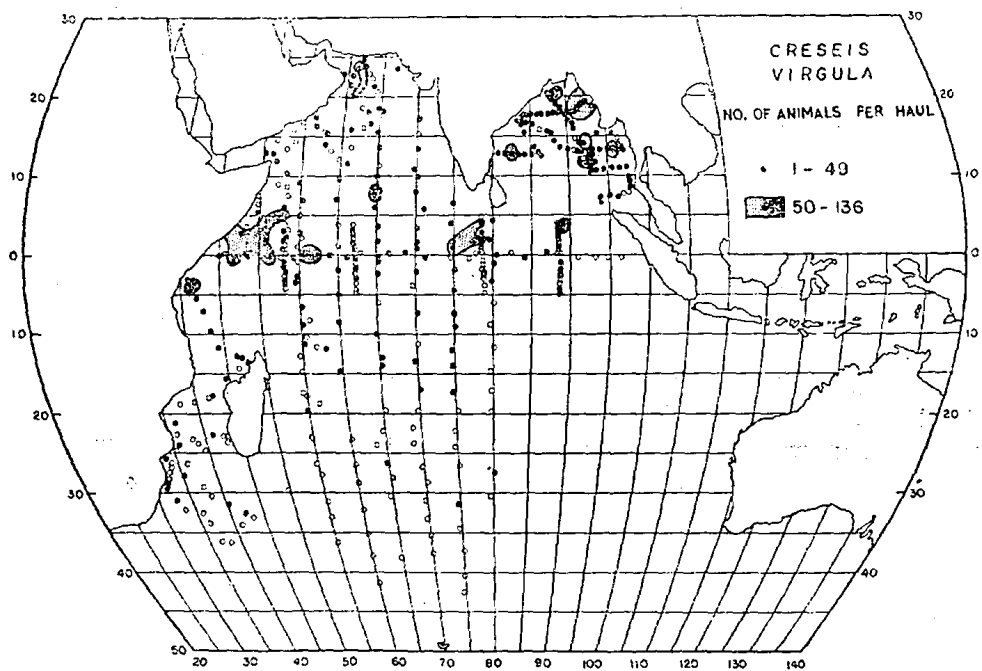
Styliola subula Quoy and Gaimard

Meisenheimer (1905) was of the opinion that *S. subula* avoids strictly tropical waters and is most common beyond the 10° or 15° parallels, away from the equator. This sort of antitropical** distribution was not observed by Tesch (1948) since he noticed continuous distribution in the Pacific from the north central through the equatorial to the south central waters. Massay (1920) however, found that in the Atlantic *S. subula* avoided the very warm water near the equator. In the Pacific, McGowan (1960) points out that the distribution of the species is bisubtropical with "limited communication between the two segments of the population of the south and north subtropical Pacific". The distribution in the Indian Ocean further suggests that this is not a strictly antitropical species, since six stations of relatively high concentration were found in the western equatorial Indian Ocean (Fig. 9). However, Massay's explanation that "this species avoids the very warm water..." may still be applicable, inasmuch as the tropical maximum is in the area influenced by the cool Somali current.

The rare occurrence of the species in (1) the northern Indian Ocean (north of 7° N), (2) the southern part between 5° S and 15° S, and (3) the mid-part of the equatorial zone, may possibly be attributed to the excluding effect of high-temperature suggested by Massay, but both of the principal areas of high occurrence are mixing areas,—the terminus of the North Equatorial Current east of Africa, and the region of mixing of equatorial and subtropical water south of Madagascar (Orren 1963). Tesch (1948) noted that "there are some very rich stations at the west coast of Sumatra

*The identification of variants of *C. virgula* is not yet attempted as most of the specimens have lost their shells.

**Antitropical is defined by McGowan as follows. "Where the same or two closely related species inhabit areas both to the north and to the south of the tropical latitudes. These may be bipolar, biboreal, bitemperate or bisubtropical."

FIG. 6. The Distribution of *Clio pyramidata*.FIG. 7. The distribution of *Creseis virgula*.

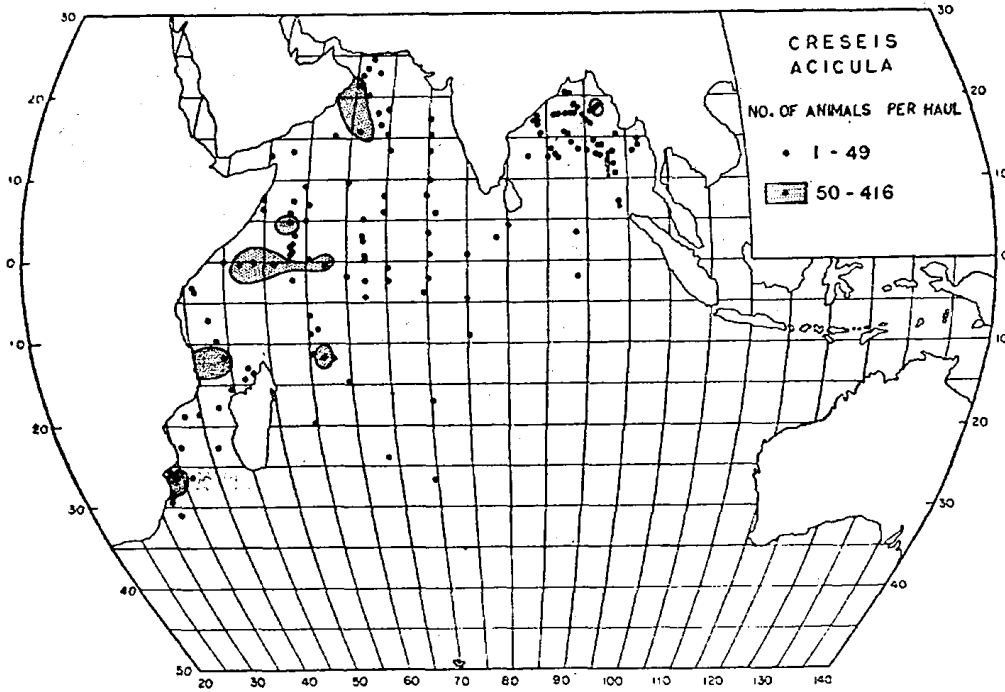


FIG. 8. The distribution of *Creseis acicula*.

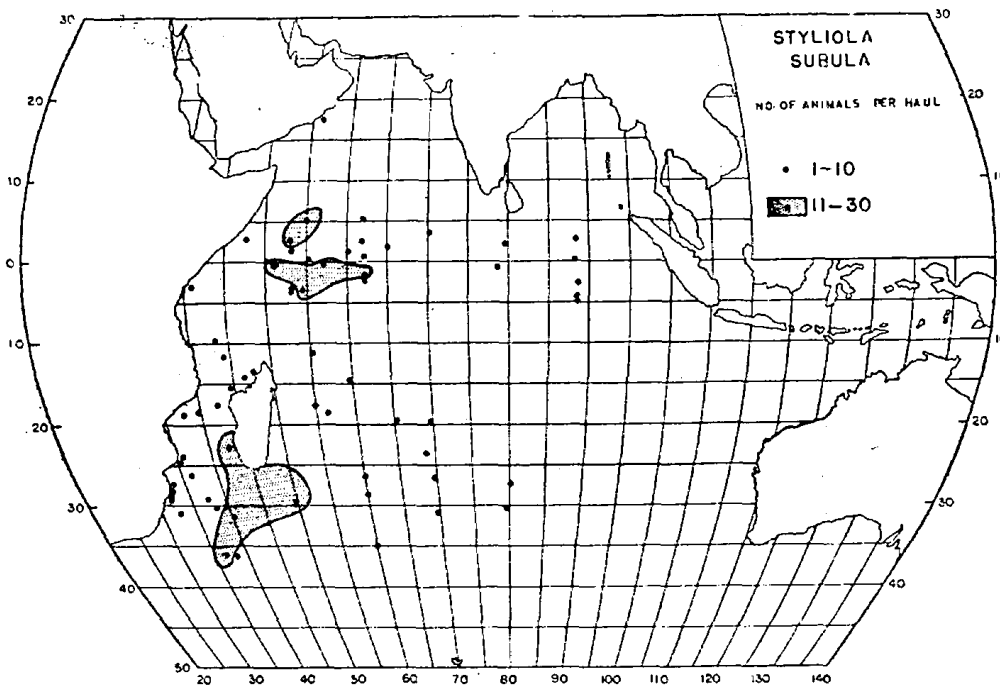


FIG. 9. The distribution of *Styliola subula*,

but on the track Nicobar-Ceylon-Seychelles it seemed rather scarce and only north of Madagascar, down to Duran was it again numerous". It is Stubbings's (1937) view that, in the Indian Ocean, this species is "more abundant between 25° S and 34° S except round the Cape of Good Hope; the scarcity in the northern part of Indian Ocean and Arabian Sea is in accordance with Meisenheimer's statements regarding its distribution. The distribution of the species on the east coast of Africa can possibly be attributed to the presence there of cooler Antarctic water flowing up the African coast".

Hyalocylix striata (Rang)

This is a typical tropical species, apparently very rare south of 20° S. The occurrence to 30° S in the Mozambique Channel may be, Tesch (1948) infers, owing to transport by the Agulhas Stream. The places of high abundance are along the equator, in the northern Arabian Sea, and in the northern and eastern parts of the Bay of Bengal (Fig. 10). According to McGowan (1960) "This species, like *L. inflata* and *D. trispinosa*, is adapted to warmer water conditions, but is able to achieve abundance only in those areas where either lateral or vertical movement of water mixes in cooler and presumably richer waters". The observed localities of high abundance are in such areas. At the western coast of Sumatra, Tesch (1948) has recorded it in every haul, sometimes in quantities of 2000 or even 3000. Stubbings (1937) too noted high concentration in the northern Arabian Sea and the Gulf of Aden.

Cuvierina columnella (Rang)

This species is most common along the equatorial zone (5° S - 5° N) and the Somali coast (Fig. 11). Previous records from Meisenheimer (1905), Stubbings (1937) and Tesch (1948) show more or less the same type of tropical distribution. Tesch (1948) noted that "from Nicobar to Durban this species was not encountered till after passing Ceylon, but from here on it was recorded at a series of stations, maximum being found at 8° 27'S, 50° 54'E. It could be followed up to Durban and it disappeared again on the route to Cape Town. Two largest catches were made close together at the west Sumatran coast by Dana". The scarcity of the species north of 10° N remains a point of interest.

Diacria quadridentata (Lesueur)

This species is found particularly in equatorial Indian Ocean (Fig. 12). High abundance is again noted along the Somali coast. Occurrences beyond 30° S are rare. Tesch (1948) found *D. quadridentata* throughout the tropical region.

Diacria trispinosa (Lesueur)

The distribution of this species in the Indian Ocean is similar to that observed by Tesch (1946) in the Atlantic. It ranges widely in tropical temperate waters, from 40° N to 35° S. High concentrations are noted along the east coast of Africa between 5° N and 15° S, 40° E and 60° E (Fig. 13). It should be pointed out, however, that forms clearly recognizable as adults of *D. trispinosa* occurred in five stations only out of

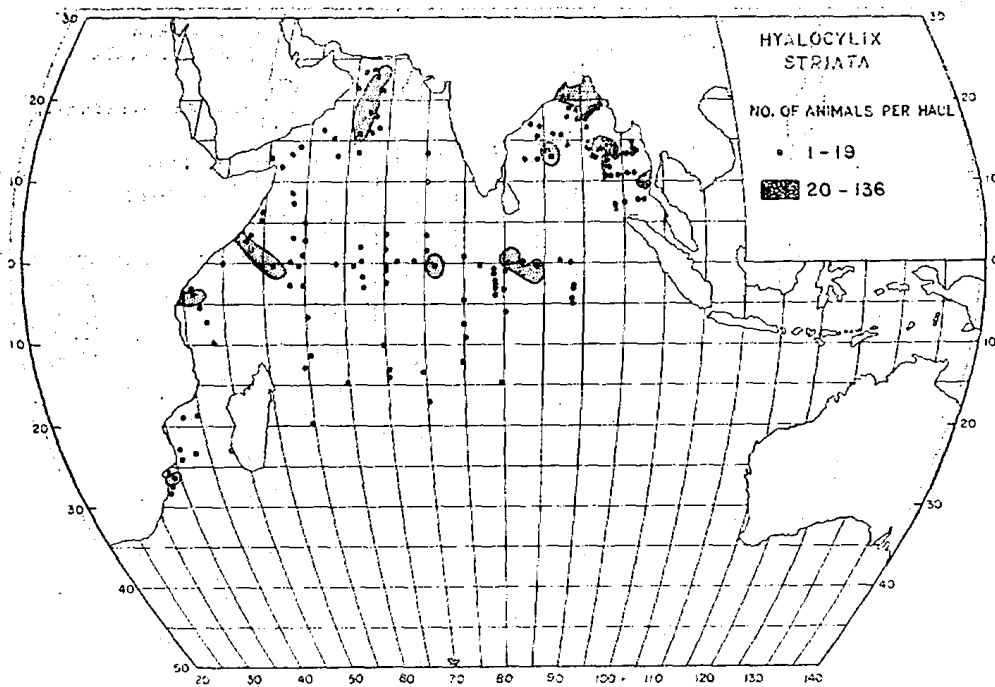


FIG. 10. The distribution of *Hyalocylix striata*.

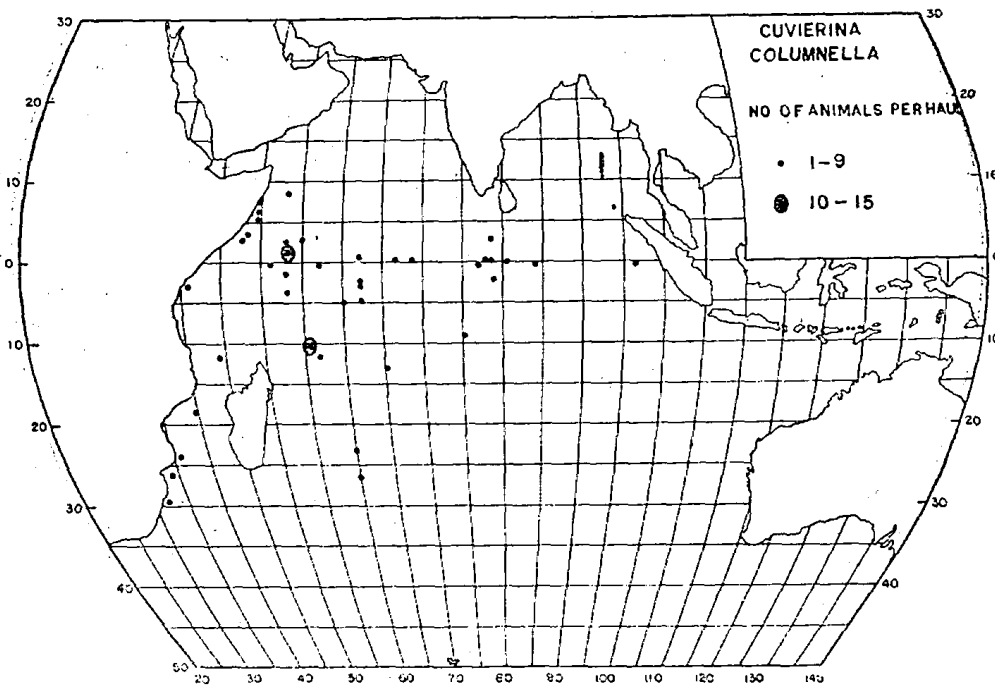


FIG. 11. The distribution of *Cuvierina columnella*.

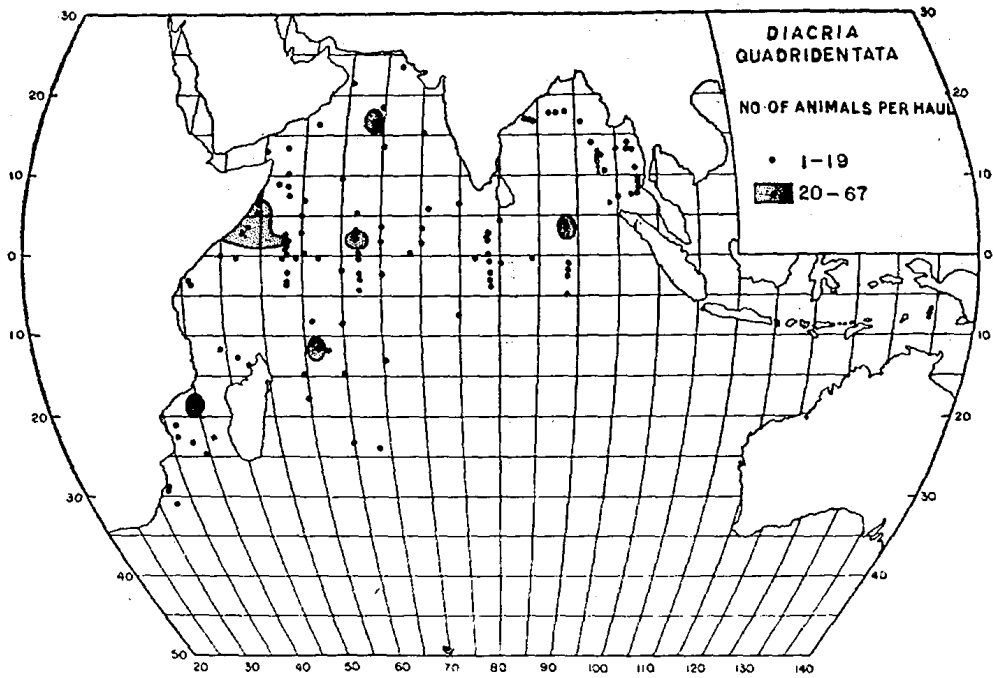


FIG. 12. The distribution of *Diacria quadridentata*.

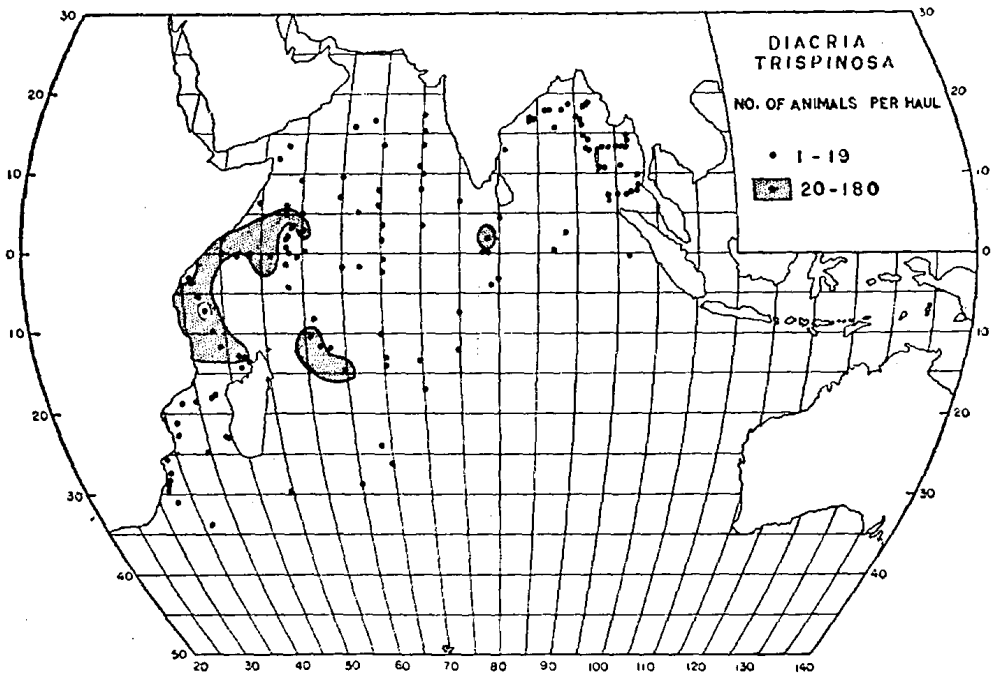


FIG. 13. The distribution of *Diacria trispinosa*.

395 (Fig. 13) and the forms observed in the remaining stations were more or less immatures or juveniles corresponding to *Cleodora compressa* (Souleyet); these juveniles belong mostly to *D. trispinosa* but some of these should perhaps be referred to *D. quadridentata* and the difficulty of separating juveniles of the cosomes according to species is too well known to need emphasis here. The distribution observed in figure 13 is in good agreement with the published records of Stubbings (1937) and Meisenheimer (1905). The paucity of this species in the northern Arabian sea (see Fig. 13) had been remarked upon by Stubbings (1937).

Cavolinia longirostris (Lesueur)

This species is not common south of 20° S (Fig. 14). Places of relatively high concentration are patchily distributed throughout the tropical zone. Tesch (1948) has recorded high abundance at the west coast of Sumatra. The records of Stubbings (1937) show that this species is very common in the Arabian Sea.

Cavolinia globulosa (Rang)

The distribution of this somewhat rare tropical species is centred at the equator, 10° N and 10° S. It is not common in the Bay of Bengal, the Arabian Sea and the central part of the southern Indian Ocean (Fig. 15). Tesch (1948) observed that this species is practically confined to the tropical belt of the Indo-Pacific and more common in Indo-Malayan waters and in the Indian Ocean; this is "foreign to the Atlantic". It is perhaps due to its rigid stenothermic habit that the species is unable to round the Cape of Good Hope. In the Pacific the occurrence is also rare (McGowan 1960). Stubbings (1937) was of the opinion that "this is common in the Bay of Bengal and eastern part of the Indian Ocean, and probably occurs almost as frequently in at least the central and southern parts of the Arabian sea; at present it is unknown from the northern part of the Gulf of Oman".

Cavolinia inflexa (Lesueur)

Stubbings (1937) was under the impression that except for a single record in the Bay of Bengal and his single shell-less specimen from the central Arabian Sea, all the previous records for the species in the Indian Ocean are south of the equator. Tesch (1948) recorded "many in Indo-Malayan waters and in the Indian Ocean up to S. of Durban". Meisenheimer (1905) found it to be most common between 20° S and 40° S. The present records are mostly from off the Somali coast and the western equatorial Indian Ocean, 15° N to 10° S and west of 65° E (Fig. 16). This is the cooler part of the tropical zone, enriched by the Somali upwelling. The scarcity of the species in the northern Indian Ocean remains a matter for further investigation.

Cavolinia uncinata (Rang)

Tesch (1948) concluded that "in accordance with Atlantic records this species seems to keep in the Indo-Pacific within tropical boundaries, 30° lat. being rarely

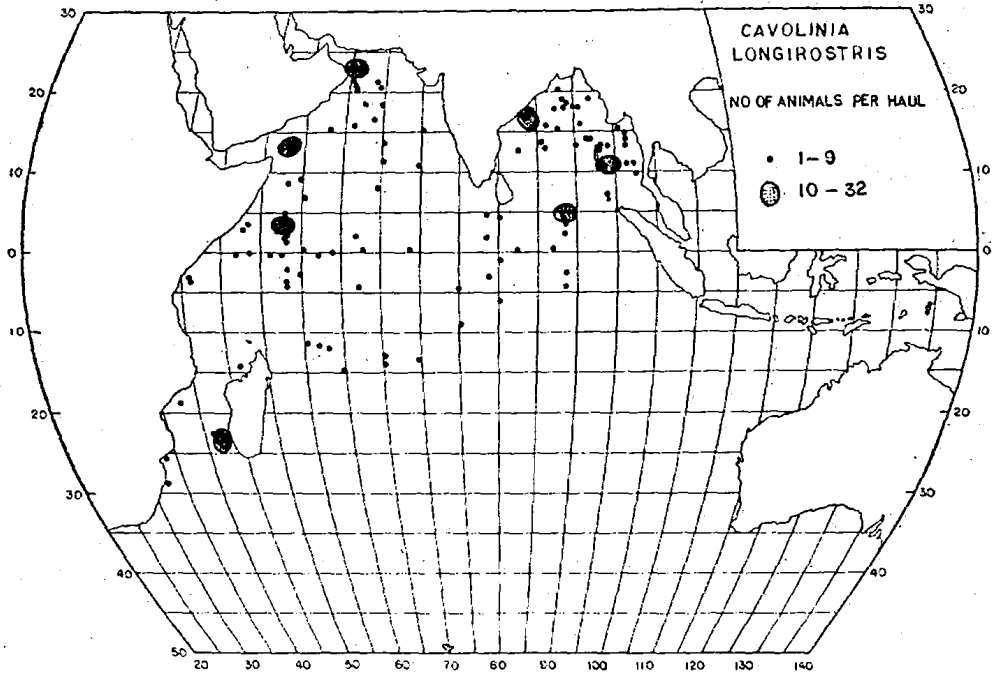


FIG. 14. The distribution of *Cavolinia longirostris*.

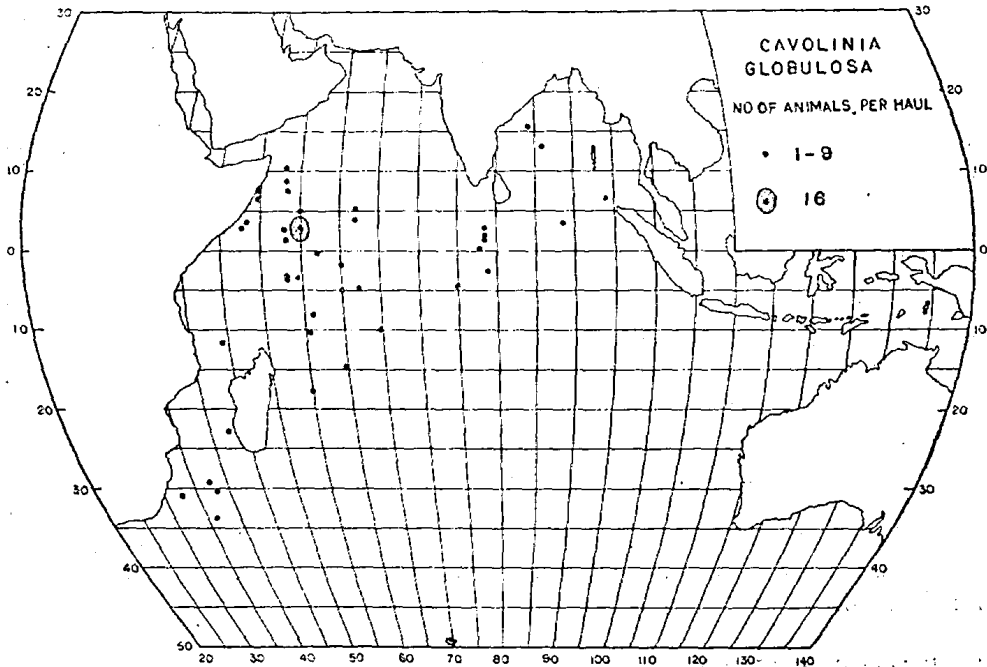


FIG. 15. The distribution of *Cavolinia globulosa*.

reached. Within the tropic circles it is widely spread, but such large swarms as were sometimes encountered by the 'Dana' in the Atlantic (Tesch 1946) never occurred in the Indo-Pacific, the largest number being only 69 per haul at the West Sumatran coast...." On the basis of present observations and earlier records on the distribution of this species, it may be said that it occurs in the Bay of Bengal but is very rare in the Arabian sea and to the south of the equator (Fig. 17).

Cavolinia gibbosa (Rang)

The rarity of this species in all the world oceans is borne out by the single record in the present collections, at 10° S - 65° E (Fig. 17). In spite of intensive search along the west Sumatran coast Tesch could not find a single individual. All the previous records indicate that this species is more common in higher latitudes in the south-western part of the Indian Ocean. It is unknown in the northern Indian Ocean.

DISCUSSION

The results derived from the present introductory study of the IIOE Collections do not permit definitive conclusions regarding the distribution of euthecosomes. This report is intended to provide a comparison of the first results with records from the early work in the Indian Ocean. The high concentration of most of the species in the region off the Somali coast suggests that this is a suitable habitat in several respects. The characteristic features of not only upwelling and enrichment of surface water but also a wide range of temperature probably provides a suitable environment for the breeding, spawning and feeding of several species of euthecosomes. Tesch (1948) has remarked on the great abundance of euthecosomes from west of Sumatra. As only two collections from off the coast of Sumatra have been examined in the present study, detailed comparisons with the results of Tesch will be attempted later. The Central zone of the southern Indian Ocean, 20°-45° S and 50°-85° E, appears to be sparsely populated by euthecosomes as is evidenced by the low numbers of all species. Because of the southerly transport between Mozambique and Africa, almost all species which occurred off the Somali coast were found to occur in the Mozambique Channel also. Scarcity or absence in the Arabian Sea and Bay of Bengal of certain otherwise common species, such as *Cuvierina columnella*, *Styliola subula*, *Cavolinia globulosa*, and *C. inflexa* is noteworthy. Possible reasons for this paucity in distribution can be considered later from the examination of further collections available at IOBC and in relation to environmental factors. As only a few specimens in the collections still retained their shells, identification of different varieties of the several species has not yet been attempted. Juveniles of uncertain identity and distorted specimens have also been excluded from this report. In due course, attempts will be made to identify the variants and juveniles.

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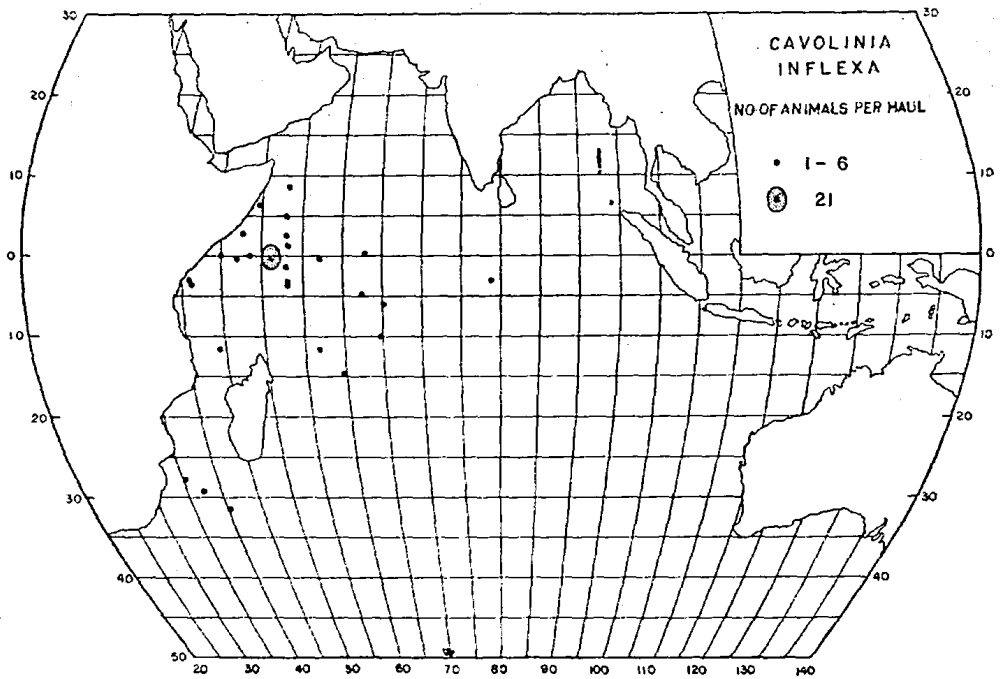


FIG. 16. The distribution of *Cavolinia inflexa*.

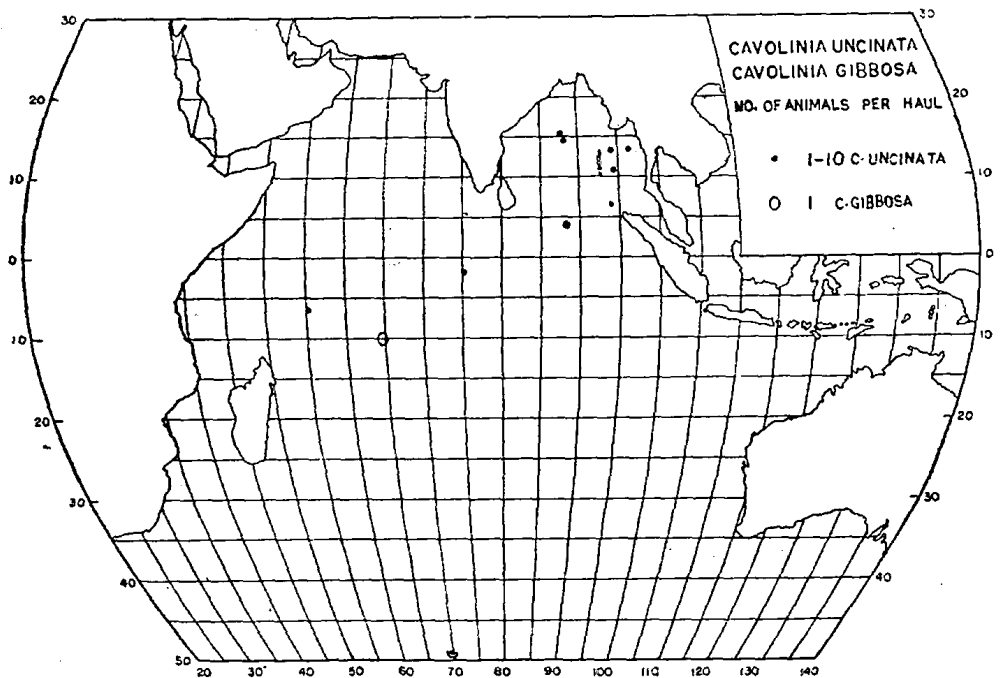


FIG. 17. The distribution of *Cavolinia uncinata* and *C. gibbosa*.

guidance and advice. I am also thankful to Mr. L. R. Kasturirangan, for going through this paper and offering me suggestions.

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