EUPHAUSIIDS OF THE WEST COAST OF INDIA

CMFRI SPECIAL PUBLICATION NO. 78

K.J. MATHEW
GISHA SIVAN
P.K. KRISHNAKUMAR
SOMY KURIAKOSE

CENTRAL MARINE FISHERIES RESEARCH INSTITUTE
(INDIAN COUNCIL OF AGRICULTURAL RESEARCH)
P.B. NO. 1603, COCHIN-682 014, INDIA

JULY 2003

EUPHAUSIACEA (CRUSTACEA : ZOOPLANKTON) OF THE EXCLUSIVE ECONOMIC ZONE OF THE WEST COAST OF INDIA

K.J. MATHEW, GISHA SIVAN, P.K. KRISHNAKUMAR AND SOMY KURIAKOSE

ABSTRACT

The euphausiids (Class Crustacea: Order Euphausiacea) one of the major components of the marine zooplankton occurring in the EEZ of the west coast of India (eastern Arabian Sea) and collected during the cruises of FORV *Sagar Sampada* during 1985-1992 period from the epipelagic zone were subjected to specieswise study for their distribution in space and time and for their ecology and biology. Seventeen species were encountered of which *Pseudeuphasia latifrons* (at an average density of 258/1000m^3 of water), *Euphausiia diomedeae* (1,256), *E. sibogae* (1,437), *Nematoscelis gracilis* (309), *Stylocheiron armatum* (230) and *S. affine* (216) were the most abundant and cosmopolitan in occurrence. The other 17 species namely *Thysanopoda monacantha, T. tricuspidata, T. astylata, E. tenera, E. pseudogibba, Nematobrachion flexipes, S. suhmii, S. microphthalma, S. longicorne, S. abbreviatum* and *S. maximum* were rather sparsely distributed and their average number per 1000m^3 of water ranged between 10 and 151 only. The major species exhibited marked variations in population during different months and seasons mainly depending on the changes in the environment. All the major species had a southwest monsoon and post monsoon abundance. The euphausiids had the maximum density of 3,942 per 1000m^3 in the continental shelf waters where the depth to the bottom ranged from 51 to 100 m. The southern latitudes of the study area always supported more euphausiids, the

reason being environmental. The populations gradually tapered to the north. A pronounced variation in the day/night abundance was observed for majority of the species indicating diurnal vertical migration. *E. diomedeae* was found to perform strong vertical migration against *S. affine* which migrated the least. The different life stages such as adults, juveniles and larvae exhibited varying degrees of vertical migration, always the larvae being the least migrating. Notable variations in the different latitudinal sectors during the major seasons and months were shown by the major species, a phenomenon attributed to changes in the environment. The pattern of movement of euphausiids between shelf and oceanic waters during different seasons showed that from an equilibrium level during the premonsoon season the population increased in the shelf region during the monsoon and reached the maximum during the postmonsoon season. However, marked variations were found among individual species. The monthly variations among species in the shelf and oceanic waters were also worked out. A study of latitudinal and seasonal variations in the shelf and oceanic areas for the various species threw some light on their north-south movement during different seasons in the different environments. In this tropical environment all the species showed almost continuous breeding with varying intensities. However, a study of the monthly abundance of the adults, the juveniles and the larvae and also the spermatophore and egg bearing animals in the population gave indications on the breeding periods of the major species; the peak periods being April, May and November for *P. latifrons*, April, May, July and November for *E. diomedeae*, August, September and October for *E. sibogae*, July and November for *N. gracilis*, March, April and May for *S. armatum* and April, August, September and November for *S. affine*. A study of the spermatophore bearing males and females indicated that the copulation success was minimum among the various species.

The numerical abundance of each species and total euphausiids estimated for space and time and in their different combinations were statistically tested for significance. The biodiversity analyses were performed to calculate richness, diversity and evenness of species in each station using univariate techniques. Multivariate techniques were used to evaluate both among the stations and among the sites patterns in overall biodiversity.

3

SPATIAL DISTRIBUTION OF EUPHAUSIIDS

Gopalakrishnan and Brinton (1969) highlighted the significance of looking into the distribution of Euphausiacea as a whole in space. According to them as majority of the euphausiid material consists of larvae and immature specimens, as all the species pass through similar developmental stages and as the younger stages of most species are restricted to the near surface strata, it is to be expected that the euphausiid community as a whole is representatively sampled. Their further reasoning towards this point is concerned with the appendages that function in feeding, based on which the genera are distinguished. Whether the food is gathered selectively or by filtering, those species whose feeding habits have been studied are generally recognised as omnivorous and, hence, play similar role in the food chain. This may be particularly true in the epipelagic part of the tropical zone. Therefore, they concluded that euphausiids constitute an ecological entity in a broad sense. Keeping in view of the above reasons, the euphausiids as a whole are considered in the present studies apart from a specieswise treatment given for all the parameters.

Euphausiids in general

The euphausiids as a group were found widely and abundantly distributed in the present study area comprising the Arabian Sea part of the EEZ (Fig. 11). Their average numerical density in the epipelagic zone (0 to 150 m) was estimated at 3,170 per 1000m^3 of water filtered. (All the numerical values mentioned hereafter will be number per 1000 m3 of water filtered by the sampling net). In a preliminary study made by Mathew *et al.* (1990) the average density of euphausiids in the same area was estimated as 3,680 which is higher than the present value . (This higher value might have crept in by error on the mistaken identity of the earlier larval stages of euphausiids with that of sergestids and decapod larvae while sorting the zooplankton taxa). However, the present value is highly comparable with the average values obtained for any other sea areas. Gopalakrishnan and Brinton (1969) estimated the euphausiid abundance in the range of 2,500 to 4,000 for the area north of the equator in the Indian Ocean and more than 1,000 for the major part of the Indian Ocean. Ponomareva (1966) estimated the euphausiid density for the entire Pacific Ocean and found that majority of the areas comprising the tropics and the subtropics contained euphausiids at the rate of 100-500. However,

Gopalakrishnan and Brinton (1969) and Mauchline and Fisher (1969) are of the opinion that the estimates of Ponomareva are very conservative. They are of the opinion that the population density in the tropical Indian Ocean are proportionately large compared with high density areas in the temperate and Subarctic Pacific and that the maximum Indian Ocean densities are at least as high and probably higher than those reported for the Pacific. Such a situation of high euphausiid production is but normal for the tropical Indian Ocean including the Arabian Sea where certain dynamic environmental forces operate simultaneously which favour high production at the various levels. These include, the bimonthly reversal of the surface currents transporting nutrient rich water from the Gulf areas, formation of water masses from different sources that occupy different depth zones encouraging production and the intense upwelling in some areas which bring up nutrient rich water to the euphotic zone.

In the present investigation the euphausiids were taken from all the stations sampled irrespective of localities or seasons. They were especially abundant south of 15°N latitude, the area encompassing the Lakshadweep waters. The Lakshadweep waters which otherwise would have remained low in productivity due to the poor mixing between surface and deeper water on account of the prevailing strong tropical thermocline are always rich in biological components of all kinds because of the coral lagoons which support very high productivity at the primary level. The outgoing nutrient rich water from the lagoons during low tides enrich the open sea where high rate of production results at all levels. This is true of euphausiids also.

The highest number of euphausiids ever obtained from a single station was 42,603 per 1000m^3 of water which was from an oceanic station sampled during the night in November off the west of Minicoy Island. Localities of very high density beyond 10,000 were mostly outside the continental shelf edge. Out of the 30 stations which yielded more than 10,000 per 1000 m^3 of water, 10 stations were from the Lakshadweep Sea.

The euphausiids were especially abundant within and outside the Wadge Bank off Kanyakumari an area both biologically and ecologically significant for being the confluence of the Arabian Sea, the Bay of Bengal and the Indian Ocean. Thus the second locality of high euphausiid abundance was the Wadge Bank area south of Kanyakumari in the continental shelf where they occurred at the rate of 37,042 in July. Seven stations in this area contributed to more than 10,000 euphausiids per 1000 m^3 of water.

In the rest of the area studied, the euphausiids often aggregated especially within the continental shelf area. Areas of such high concentrations were noticed off Kandla, Mumbai, Ratnagiri, Goa and between Mangalore and Cochin.

The euphausiids being a highly schooling group of organisms, some of the dominant species especially the epipelagic species namely *Pseudeuphausia latifrons*, *Euphausia diomedeae*, *E. sibogae*, *Nematoscelis gracilis*, *Stylocheiron armatum* and *S. affine*

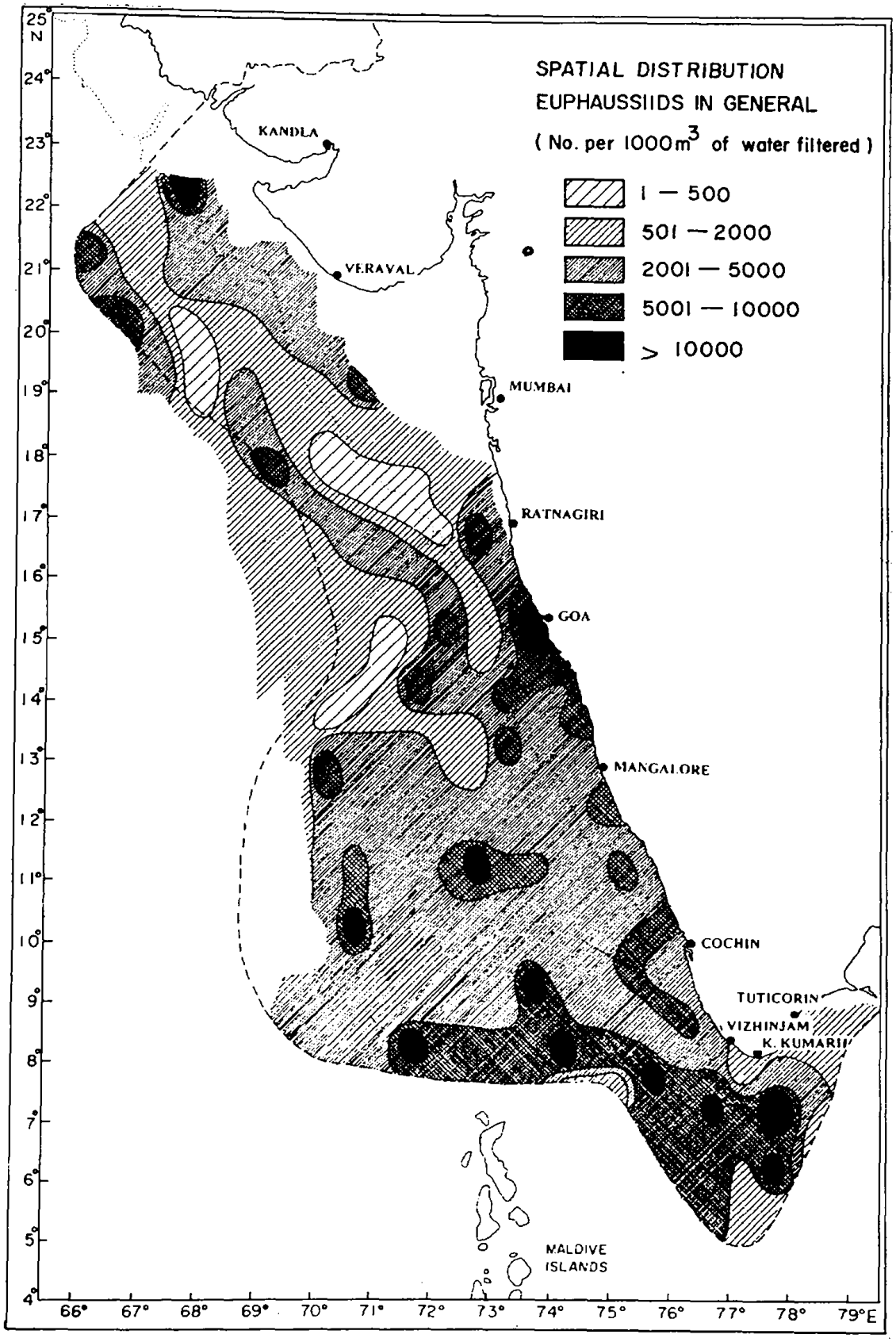

Fig. 11. Spatial distribution of total euphausiids in the EEZ of the west coast of India.

can occur in heavy concentrations and this is the main reason for the presence of very high numbers in certain localities.

Thysanopoda monacantha Ortmann 1893 (Fig. 12)

Out of the 493 samples analysed from the study area 150 contained this species of which 39 samples were from north of 10°N. One sample from 15°40'N72°00'E west of Goa contained this species and this was the northern most point of record ever made for *T.monacantha* in the Arabian Sea. The species was represented mostly by larvae and juveniles.

This oceanic mesopelagic species inhabiting between 140 and 1,000 m depths is widely and abundantly distributed in the Arabian sea south of 15°N (Fig. 13). However, being large in size its adult specimens are seldom caught in the standard zooplankton nets and hence a correct evaluation of its population density is not possible unless data are available from different types of gears.

The maximum density at which the species occurred was 615 west of Minicoy Island. The species occurred in fairly good numbers (>200/1000 m^3) at 8 stations around Minicoy and between 100 and 200 at 24 stations again in the Lakshadweep waters. Apart from the Lakshadweep waters high abundance of *T. monacantha* was noticed southwest of Wadge Bank away from the shelf area. The two instances of its larvae entering the shelf area was at 12°00'N 74°34'E at a station with 87 m depth and at 11°01'N 75°27'E where the depth was just 50 m.

According to Brinton and Gopalakrishnan (1973) the southern limit of this species in the Arabian Sea is along the 10°N parallel which forms an effective barrier for many of the oceanic species, the quality of water north of 10°N being "brackish" due to the

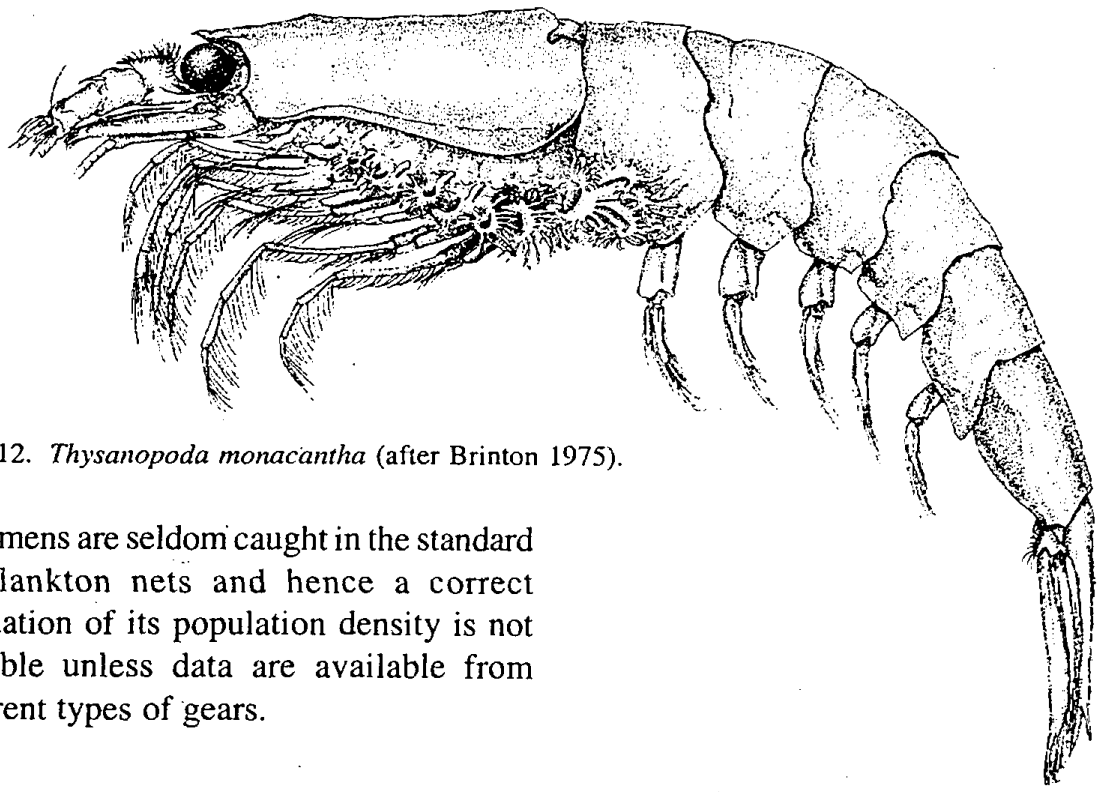

Fig. 12. *Thysanopoda monacantha* (after Brinton 1975).

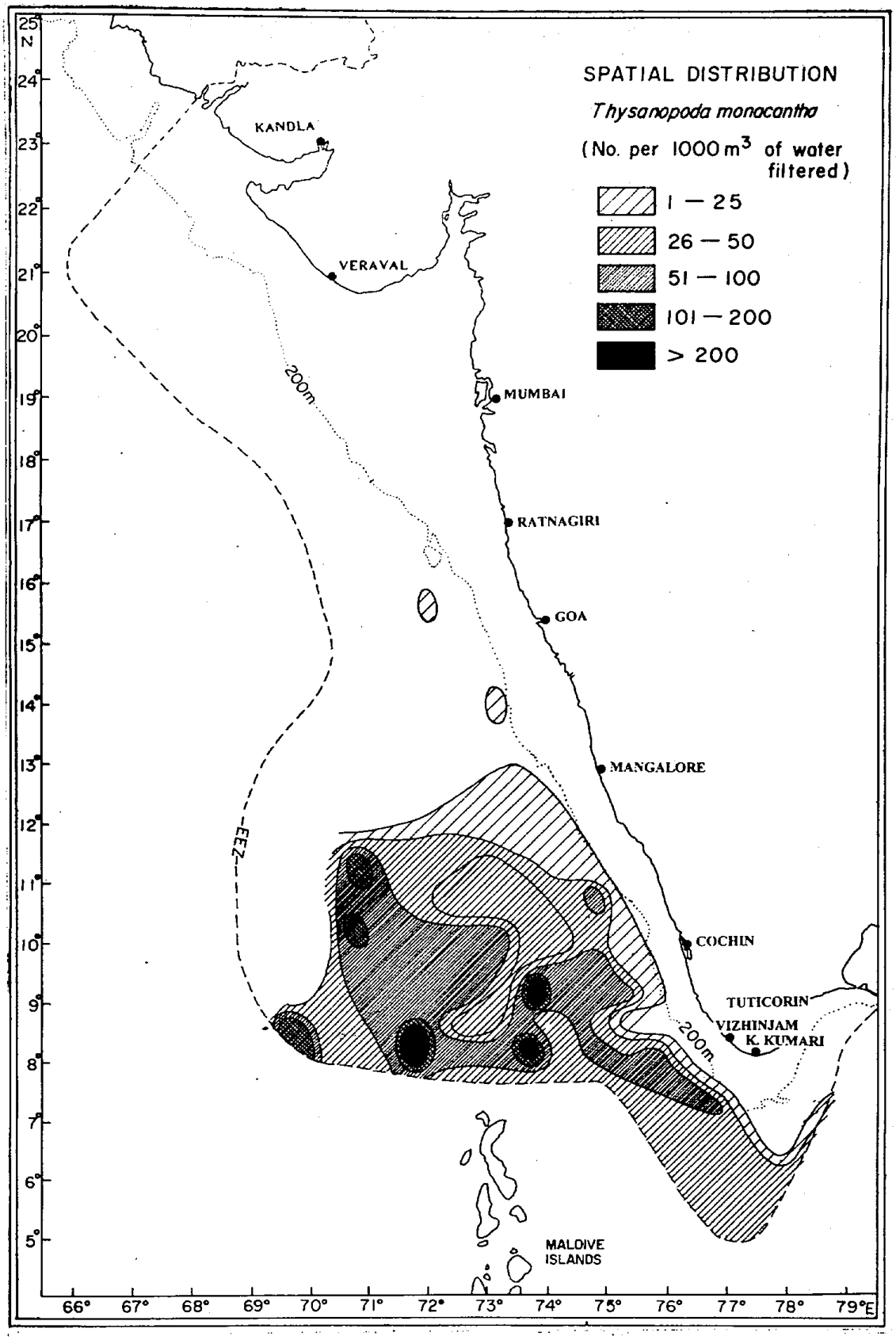

Fig. 13. Spatial distribution of *Thysanopoda monacantha* in the EEZ of the west coast of India.

land run off and the enclosed northern boundary.

T. monacantha has been recorded by several authors from different parts of the Indian Ocean. Some of the records relevant from the Arabian Sea and contiguous areas are worth mentioning. Tattersall (1939) who worked on material collected during the *John Murray Expedition* found this species distributed in a number of localities in the Central Arabian Sea and the Maldive areas. Ponomareva *et al.* (1962) observed it in the Central and Southern Arabian Sea and also south of Sri Lanka. Ponomareva (1964) recorded it again in the Arabian Sea. Gopalakrishnan and Brinton (1969) found *T. monacantha* sparsely distributed at 59 locations in the equatorial waters. Sebastian (1966) reported this species from the southwest coast of India, Lakshadweep and Maldive seas. Weighman (1970) also recorded the species in the Arabian Sea. Mathew (1982) extended the northern limit of *T. monacantha* to 13°23'N.

According to Brinton and Gopalakrishnan (1973) *T. monacantha* is scarce in the Arabian Sea. However, this is not altogether correct. The reason for not obtaining this species in abundance was that (1) the net used by them i.e. The Indian Ocean Standard Net with a mesh size of 0.33 mm was not efficient enough to capture the adults of such large species and (2) their sampling depth of 200 to surface was mostly devoid of this species. Adults of *T .monacantha* were widely and frequently caught by Mathew (1980e, 1982) and Silas and Mathew (1986) with the large meshed Issac Kid Midwater Trawl from the oceanic waters of the southwest coast of India. The adults of this species were taken at a maximum rate of 1,830 specimens per one hour trawling from the Lakshadweep waters.

***Thysanopoda tricuspidata* Milne-Edwards 1837** (Fig. 14)

As in the case of *T. monacantha* the distribution is mainly by larvae and juveniles

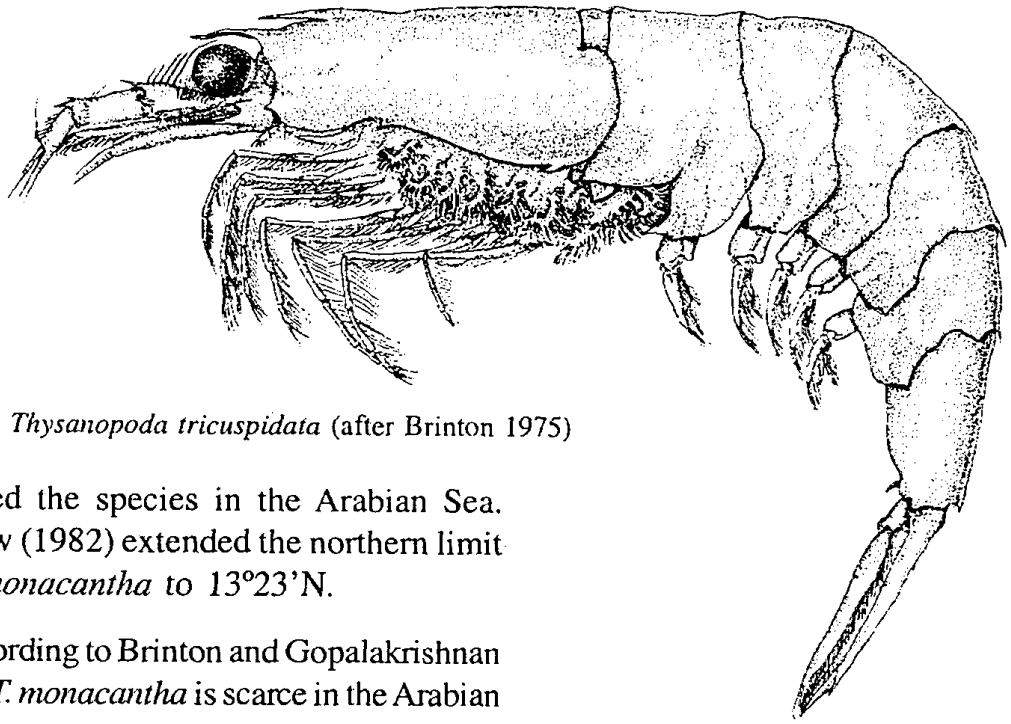

Fig. 14. *Thysanopoda tricuspidata* (after Brinton 1975)

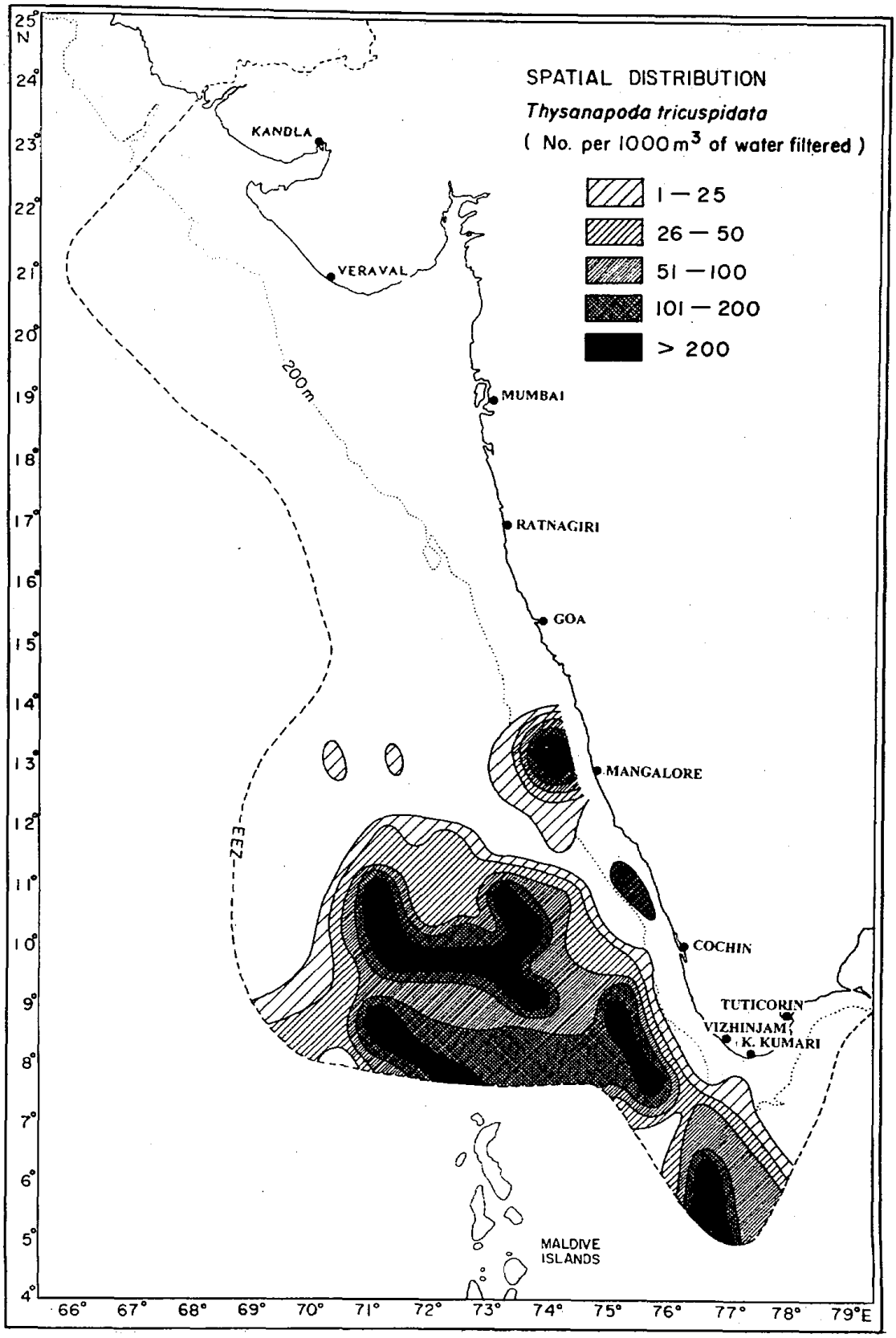

Fig. 15. Spatial distribution of *Thysanopoda tricuspidata* in the EEZ of the west coast of India.

for this large species, although it is also a widely occurring species in the oceanic waters in the tropics and subtropics of the world oceans from surface to 280 m depth. They were strictly confined to the southern parts of the present study area. They have been recorded upto 14°N (Fig. 15). *T. tricuspidata* was especially abundant in the Lakshadweep waters and south of the Wadge Bank. In the shelf area, pockets of high density were observed north of Mangalore (@ 509/1000 m^3) and between Cochin and Calicut (ca. 200/1000 m^3). The highest number ever obtained was 1,066 per 1000 m^3 of water from 08°58'N 75°00'E. Out of the 142 positive samples 34 contained this species at a rate of more than 200 per 1000 m^3 of water.

Tattersall (1912) collected *T. tricuspidata* from the northwestern Indian Ocean during the *Sea Lark* Expedition. Illig (1930) obtained it from the equatorial Indian Ocean during the *Valdivia* Expedition. The *John Murray* Expedition (Tattersall 1939) got one immature specimen from the Central Arabian Sea. Another Arabian Sea record was by Ponomareva (1964). Though in very few numbers *T. tricuspidata* was observed widely distributed in the area investigated by Sebastian (1966) off the southwest coast of India. Gopalakrishnan and Brinton (1969) found it to be one of the most abundant species in the equatorial Indian Ocean.

The north-south range of distribution of *T. tricuspidata* in the Indian Ocean according to Brinton and Gopalakrishnan (1973) is between 10°N and 25°S. However, Mathew (1980e, 1982) and Silas and Mathew (1986) extended the northern boundary of this species in the Arabian Sea upto 16°06'N which was farther than any of the earlier records including the present study.

Thysanopoda astylata Brinton 1975 (Fig.16)

This Indo-Pacific epipelagic species occurs from surface to 700 m depth in the central part of these oceans. It was originally described by Brinton (1975) partly based on *T. aequalis* described by Boden (1954). According to Brinton (1975) *T. astylata* ranges in the Indian Ocean between 10°N and 5°S while *T. aequalis* is distributed south of equator upto 35°S thereby indicating a

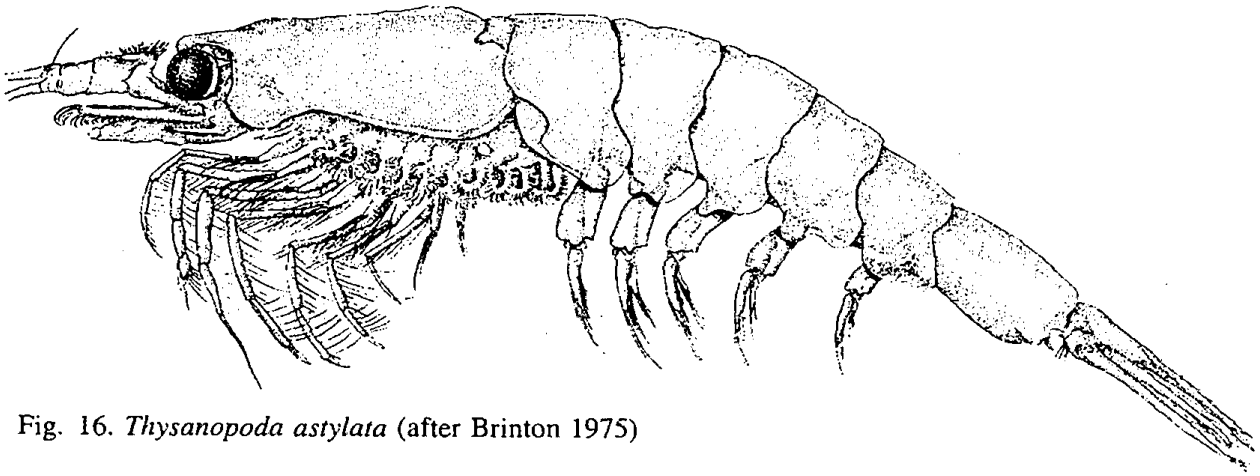

Fig. 16. *Thysanopoda astylata* (after Brinton 1975)

little overlapping in distribution in the tropics. The material from the present study area is more akin to *T. astylata.*

In the present studies the geographic distribution of this sparsely occurring species was confined to areas south of 10°30'N (Fig. 40). This purely oceanic species never intruded into the shelf waters. Its major areas of distribution were in the southern part of the Lakshadweep Sea especially around the Minicoy Island. A population density as high as 95 per 1000 m^3 of water was found west of Minicoy. In most of the localities the number never exceeded 25 per 1000 $m^3$of water.

Assuming that all the earlier records of *T. aequalis* north of equator were that of *T. astylata* the records of this species in the Arabian Sea are as follows:

Tattersall found this species in the tropical Indian Ocean (1912) and in the Arabian Sea (1939). Illig (1930) obtained a few specimens from the northwestern Indian Ocean. Weigmann (1970) recorded it in the Arabian Sea. Other records include Sebastian (1966) from Lakshadweep and Maldive seas, Ponomareva (1964) and Ponomareva *et al.* (1962) from the Central Arabian Sea, Gopalakrishnan and Brinton (1969) from the equatorial Indian Ocean and Brinton and Gopalakrishnan (1973) from the equatorial and northern Indian Ocean. Mathew (1980e, 1982) Silas and Mathew (1986) found it to be a very rare species confined to the oceanic area. Its northernmost limit as found by him reached a little north of 10°N.

Pseudeuphausia latifrons (G.O. Sars 1883) (Fig.17)

During the present investigation *P. latifrons* was represented in the EEZ from 06°N to 22°00'N (Fig. 18). Being a coastal species high density areas were observed mostly within the continental shelf especially towards the southern part. Areas of concentration were occasionally noticed beyond shelf waters also. The species was fairly abundant between 18°N and 22°N and between 07°N and 13°N. In the intermediate region between 13°N and 18°N *P. latifrons* was sparsely distributed with

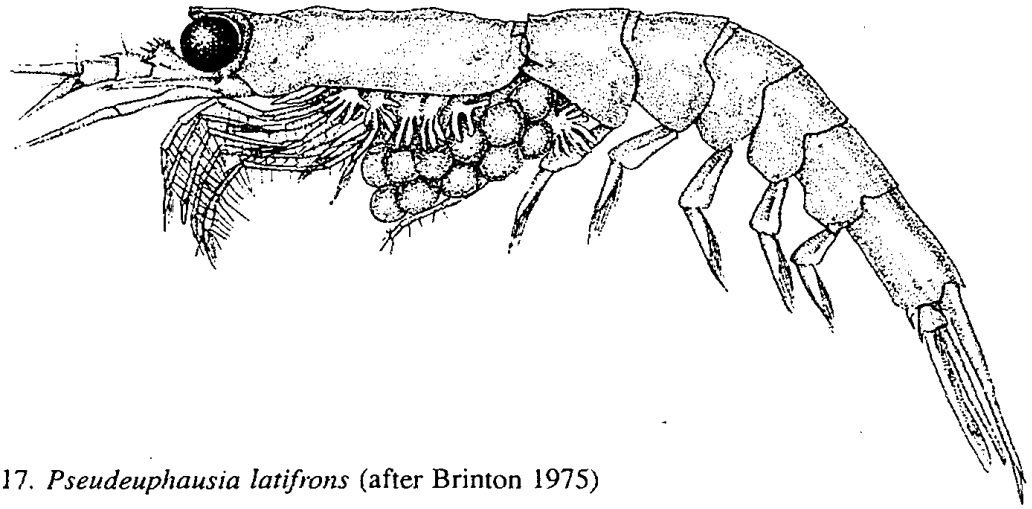

Fig. 17. *Pseudeuphausia latifrons* (after Brinton 1975)

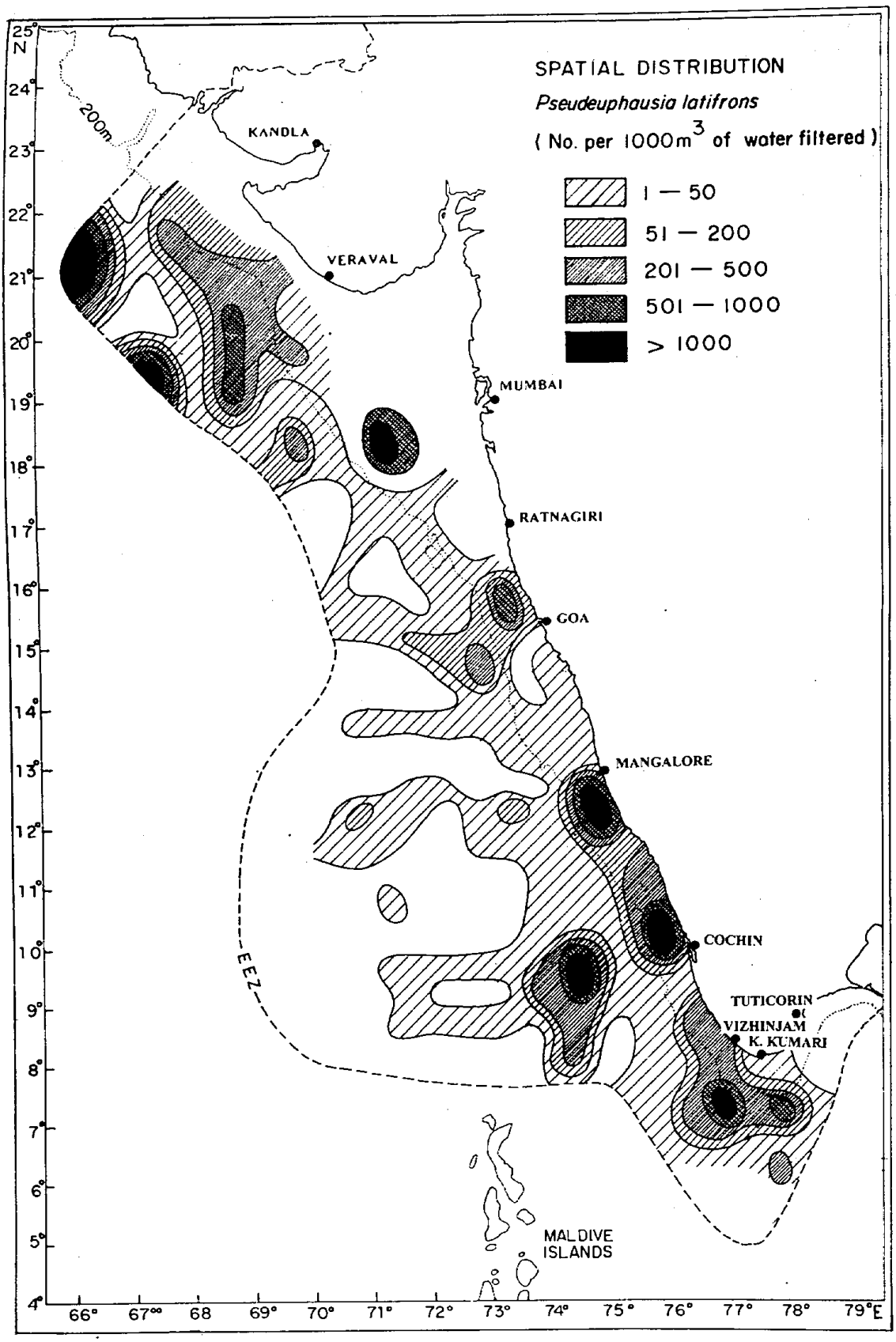

Fig. 18. Spatial distribution of *Pseudeuphausia latifrons* in the EEZ of the west coast of India.

some areas of nil occurrence. Pockets of high density beyond 1,000 per 1000 m^3 of water were found west of Veraval beyond the shelf, within and outside shelf, west and southwest of Mumbai, off Mangalore and Cochin, in the nearshore waters northeast of Minicoy and southwest of Kanyakumari. The species was sparsely distributed or even absent in most part of Lakshadweep oceanic waters though it is known to inhabit around oceanic islands. It was rarely found in the outskirts of the EEZ.

Out of the 493 samples examined this species was present in 200 samples. The numerical abundance of *P. latifrons* varied from 4 to 9,441 per 1000 m^3 of water and the highest was taken from 09°30'N 74°20'E northeast of Minicoy in the early morning in April. Among the total euphausiids *P. latifrons* ranked fourth in abundance with an average density of 258 per 1000 m 3 of water.

Tattersall (1906) was the first to record *P. latifrons* in the Indian Ocean. She obtained it from between Socotra and Lakshadweep Islands, off Galle, off Mutwall and north of Chilaw. During the *Percy Sladen Trust* Expedition (Tattersall 1912) this was encountered off Nazarath Bank. During the *John Murray* Expedition it occurred in the northern Arabian Sea (Tattersall 1939). Pillai (1957) and Sebastian (1966) obtained it from the southwest coast of India. Ponomareva (1964) recorded it in the Arabian Sea. According to Weighmann (1970) it is an abundant species in the Arabian Sea. Brinton and Gopalakrishnan (1973) observed it to be the more abundant euphausiid around the Lakshadweep Islands.

Mathew (1980e, 1982) and Silas and Mathew (1986) found *P. latifrons* to be the third abundant species in the shelf waters of the southwest coast of India where it enjoyed a widespread distribution and also very close to the coast. In the oceanic realm they found the species restricted to the continental slope and nearer to the islands.

Euphausia diomedeae Ortmann 1894 (Fig.19)

This equatorial epipelagic species occurring upto 700 m depth was the second abundant species in the study area . It was present in more than 400 stations (Fig. 20). The average density of the species in the study area amounted to 1,256 per 1000m^3 of water which accounted to 39.65 % of the total euphausiid material obtained. The species was especially abundant south of 14° N. Large concentrations occurred in the Lakshadweep waters and also south of the Wadge Bank. The highest number of 38,622 per 1000 m^3 of water was recorded in the Lakshadweep Sea west of Minicoy at 08°30'N 71°30'E. Specimens above 10,000 occurred at three localities. Pockets of high population density were present between Goa and Mangalore in the shelf area, at several locations in the Lakshadweep Sea and south and west of the Wadge Bank. Patches of high abundance were found in the northern latitudes also.

E. diomedeae is a characteristic and dominant species in the equatorial Pacific also (Brinton 1962). However, most of the distributional records of this species are from the Indian Ocean. Illig (1930) recorded it

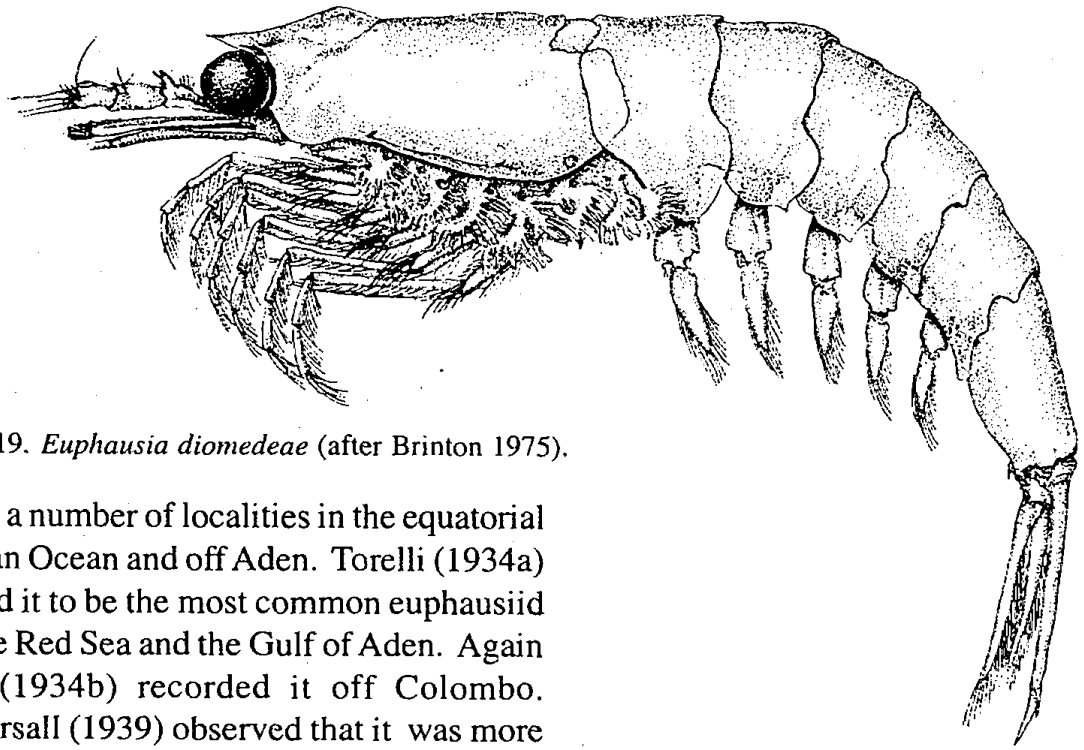

Fig. 19. *Euphausia diomedeae* (after Brinton 1975).

from a number of localities in the equatorial Indian Ocean and off Aden. Torelli (1934a) found it to be the most common euphausiid in the Red Sea and the Gulf of Aden. Again she (1934b) recorded it off Colombo. Tattersall (1939) observed that it was more concentrated in the north and the central Arabian Sea and the Gulfs of Aden and Oman. In 1962 Ponomareva *et al.* reported *E. diomedeae* from the central and western Arabian Sea and the Gulf of Oman. It was present in the Arabian Sea as found by Ponomareva (1964) during the cruises of R.V. *Vityaz*. Sebastian (1966) reported it to be the most abundant species along the southwest coast of India, the Lakshadweep and the Maldive Seas. As found by Gopalakrishnan and Brinton (1969) *E. diomedeae* was one of the most characteristic species in the equatorial Indian Ocean. It was found to be widely distributed in the full tropical belt of the Indian Ocean (Brinton and Gopalakrishnan 1973). Mathew (1980e, 1982) and Silas and Mathew (1986) observed only a relatively smaller population in the shelf waters mostly represented by larvae and juveniles. However, the found the species to be widely and abundantly distributed in the oceanic waters.

Euphausia sibogae Hansen 1908 (Fig.21)

Being categorised as an equatorial epipelagic species found from surface to 280 m depth, *E. sibogae* is the most abundantly occurring euphausiid in the epipelagic zone of the Arabian Sea. Out of the 493 samples analysed during the present study, *E. sibogae* was present in 455 samples. This species very often occur in large schools of high population density (Fig. 22). At the various stations their number frequently exceeded 5,000 per 1000 m^3 of water. The species occurred in the entire area of study from 05°30'N to 22°30'N and was especially abundant in the continental slope and oceanic areas. The density of the population was

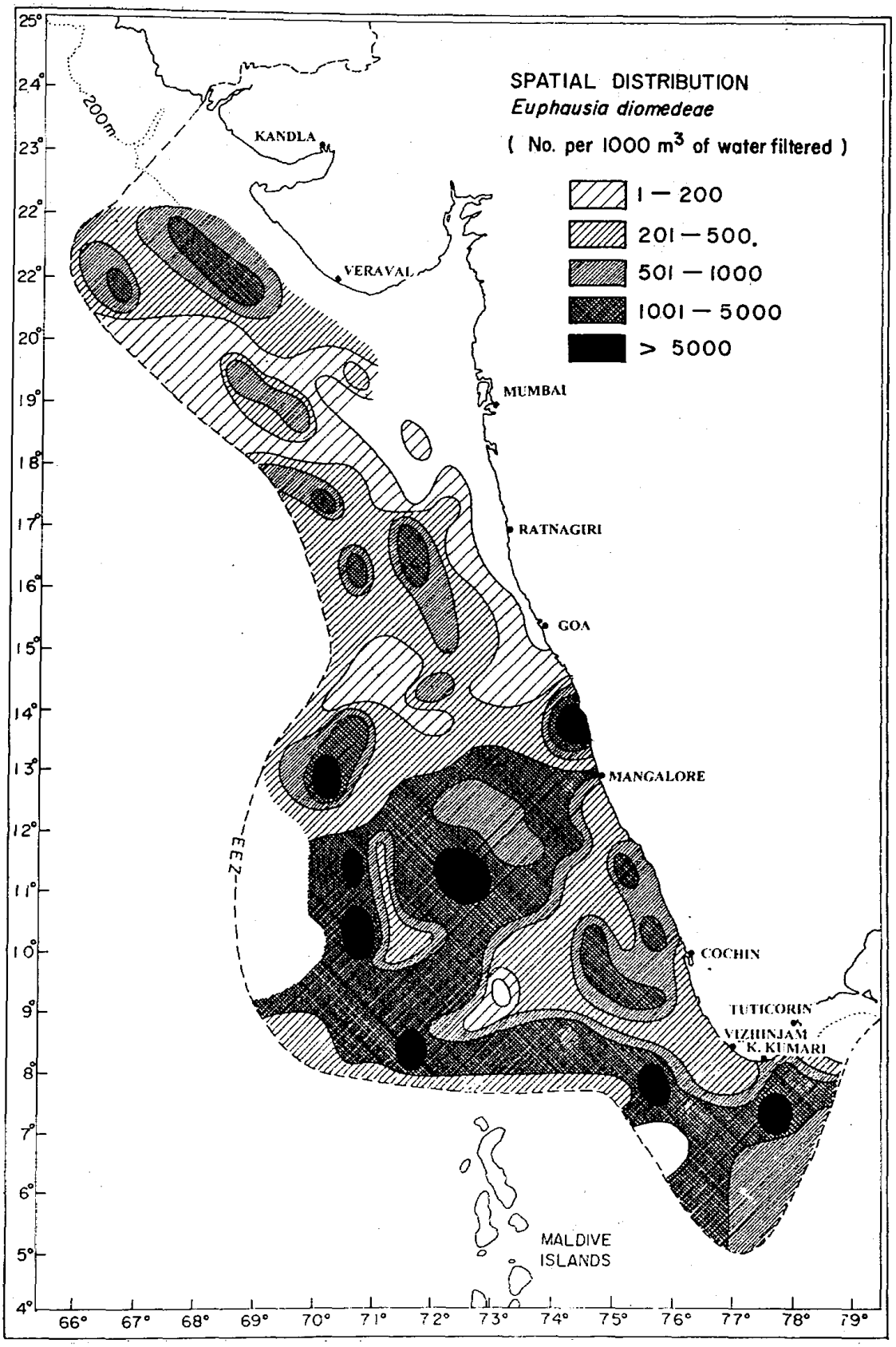

Fig. 20. Spatial distribution of *Euphausia diomedeae* in the EEZ of the west coast of India.

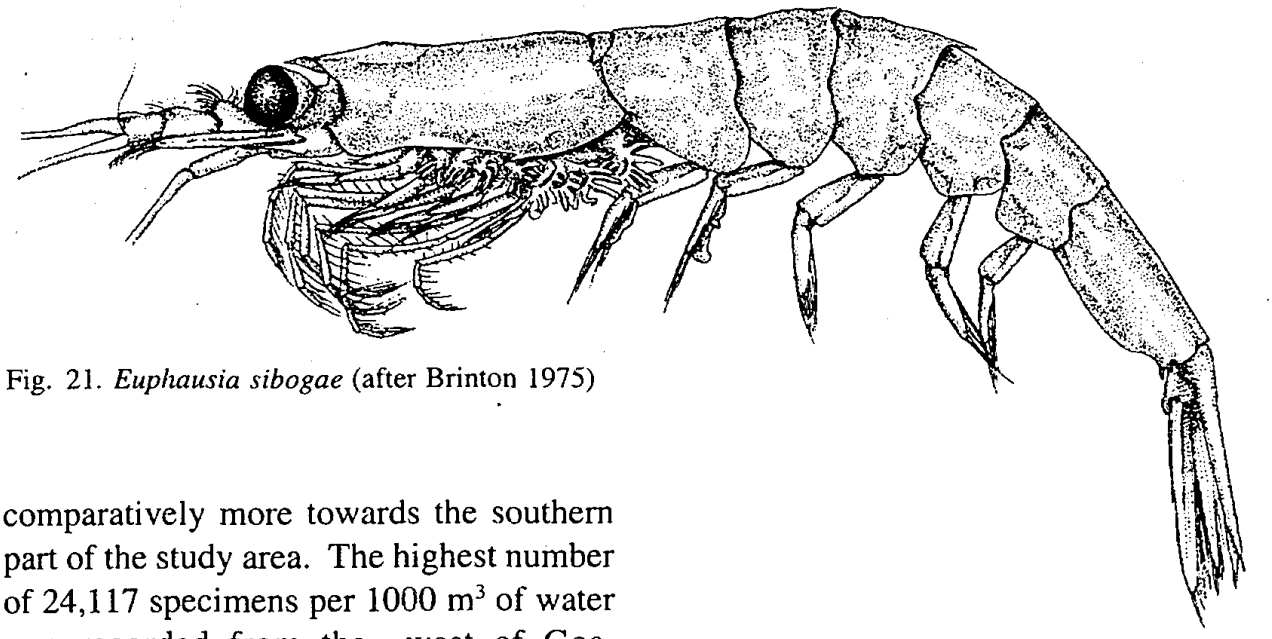

Fig. 21. *Euphausia sibogae* (after Brinton 1975)

comparatively more towards the southern part of the study area. The highest number of 24,117 specimens per 1000 m^3 of water was recorded from the west of Goa. Specimens of more than 10,000 were taken from 16 locations along the west coast. The species was moderately distributed in the Lakshdweep waters. Pockets of high density above 5,000 were found west of Kandla, southwest of Goa, between Mangalore and Cochin and west of Kanyakumari, all within the continental shelf. High population density was noticed also south of Wadge Bank in the oceanic waters. On the whole this is the most successful species in the EEZ of the west coast of India with an average density of 1,437 per 1000 m3 of water and is the most characteristic species of the Arabian Sea.

The material considered here as *E. sibogae* was reported by all the previous authors as *E. distinguenda*. However, Mathew (1982) who observed some clear variations in the morphological features of the Arabian Sea material made a thorough comparative study between the two species and concluded that the populations in the Arabian Sea belonged to *E. sibogae*. Hence all the previous records from the Arabian Sea in the name of *E. distinguenda* are considered here as *E. sibogae*.

Eventhough the *Valdivia* Expedition (Illig 1930) could not collect large numbers of this species from the Arabian Sea the *John Murray* Expedition (Tattersall 1939) found it to be the most abundant species there. Sebastian (1966) collected this species in large numbers from the southwest coast of India. Gopalakrishnan and Brinton (1969) found it in samples collected from the equatorial Indian Ocean. Weighman (1970) recorded it in the Arabian Sea. Brinton and Gopalakrishnan (1973) found this species to be widespread in the Arabian Sea. According to Mathew (1980e, 1982) and Silas and Mathew (1986) *E. sibogae* was by far the most commonest and most abundant species in the shelf waters of the southwest coast of India but in low density in the Lakshadweep area.

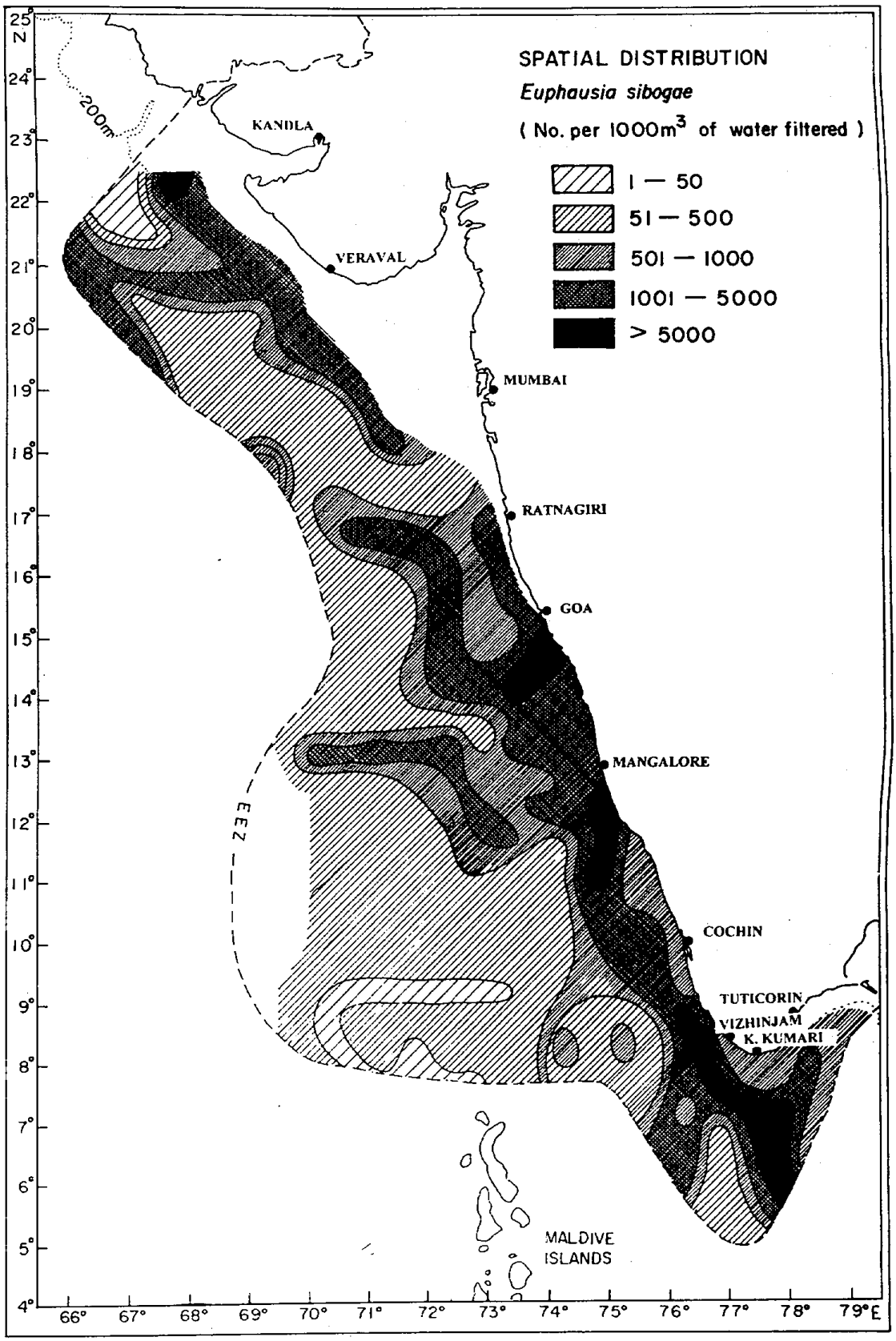

Fig. 22. Spatial distribution of *Euphausia sibogae* in the EEZ of the west coast of India.

Euphausia tenera Hansen 1905 (Fig.23)

This epipelagic species usually occupying a vertical column of 0-280 m (Brinton 1962) was rather widespread in areas south of 13° N only (Fig. 24). They were found strictly confined to oceanic waters beyond the continental shelf. High density areas were observed south of Wadge Bank, west of Minicoy and west of Mangalore. It was moderately abundant in the Lakshadweep waters. The average population density amounted to 119 per 1000 $m^3$of water. The population ranged between 11 and 849 per 1000 m^3 of water at the various locations.

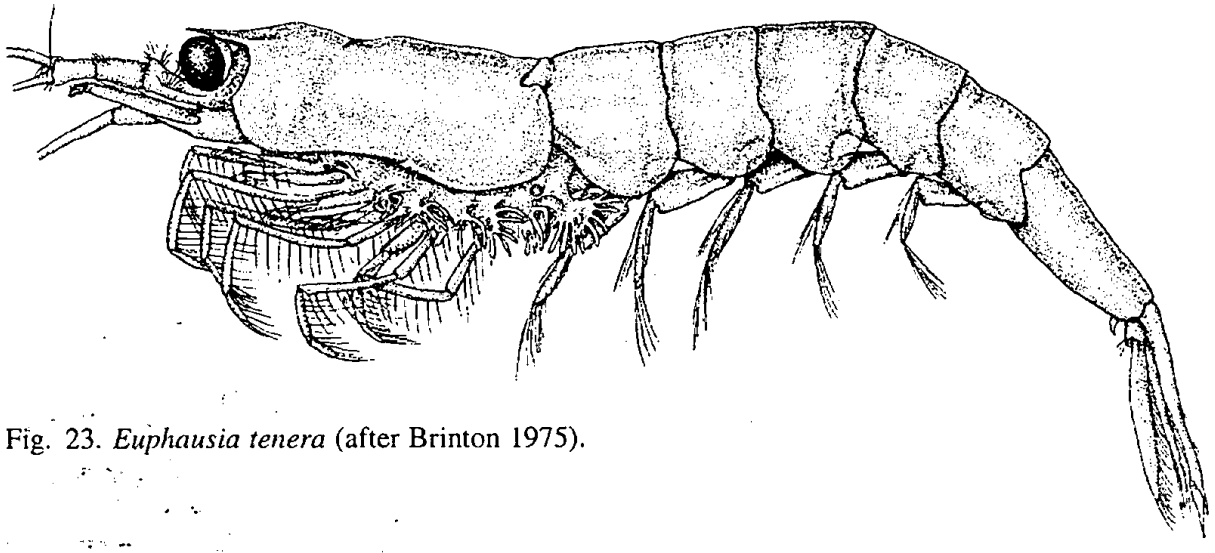

Fig. 23. *Euphausia tenera* (after Brinton 1975).

This warm water epipelagic species is fairly well distributed in the tropical and subtropical parts of the Indian Ocean. Tattersall (1912) was the first to record *E. tenera* from the Indian Ocean at places around Chagos, Mauritius, Tranqubar, Providence and Alphones islands. Illig (1930) recorded the species at 24 stations distributed over a wide geographical range in the eastern and south western Indian Ocean. In 1939 Tattersall found it in the central and southern Arabian Sea and the Maldive areas. Ponomareva (1964) collected the species from the Arabian Sea. Sebastian (1966) recorded *E. tenera* in small numbers from the southwest coast of India and the neighbouring waters. It was present in all the 94 samples collected from the equatorial Indian Ocean between 5°N and 5°S during the *Luciad* Expedition and hence the most abundant species according to Gopalakrishnan and Brinton (1969). The northernmost limit for this species in the Arabian Sea as observed by Brinton and Gopalakrishnan (1973) was 15°N in the mid Ocean. Mathew (1980e, 1982) and Silas and Mathew (1986) recorded the species as north as 11°N in the continental shelf waters and upto 12°N in the oceanic waters.

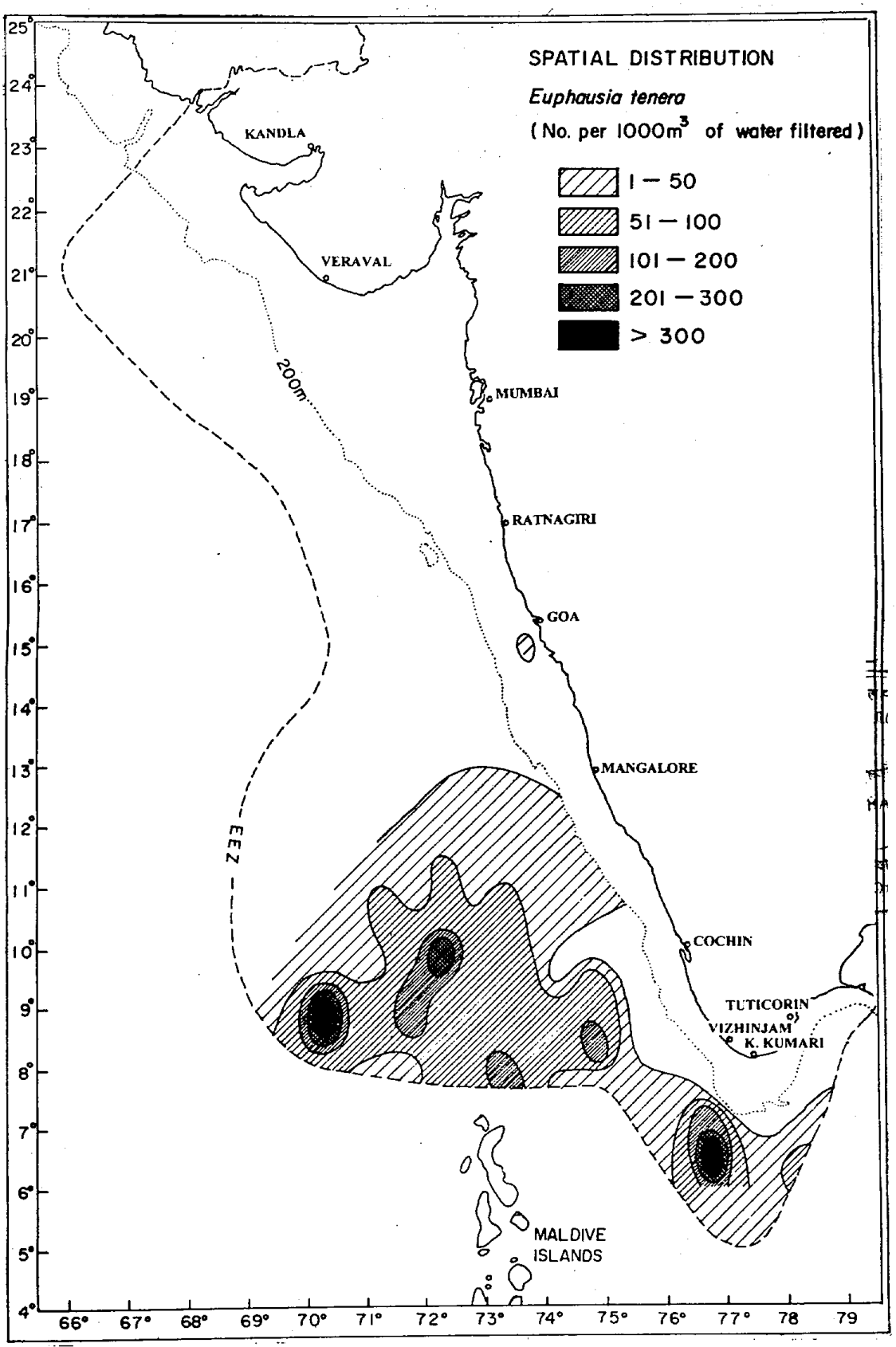

Fig. 24. Spatial distribution of *Euphausia tenera* in the EEZ of the west coast of India.

Euphausia pseudogibba Ortmann 1893 (Fig.25)

This equatorial epipelagic species was found sporadically distributed and was sparsely taken from eight stations south of 09°30'N (Fig. 40). It was confined to oceanic waters south of Wadge Bank and towards the southern part of the Lakshadweep Sea. Geographically this species occupied the same areas as occupied by another species; *Stylocheiron abbreviatum*. Its average number in the areas of occurrence was 87 per 1000 m^3 of water. The highest concentration at a density of 255 per 1000 m^3 of water was found south of Wadge Bank.

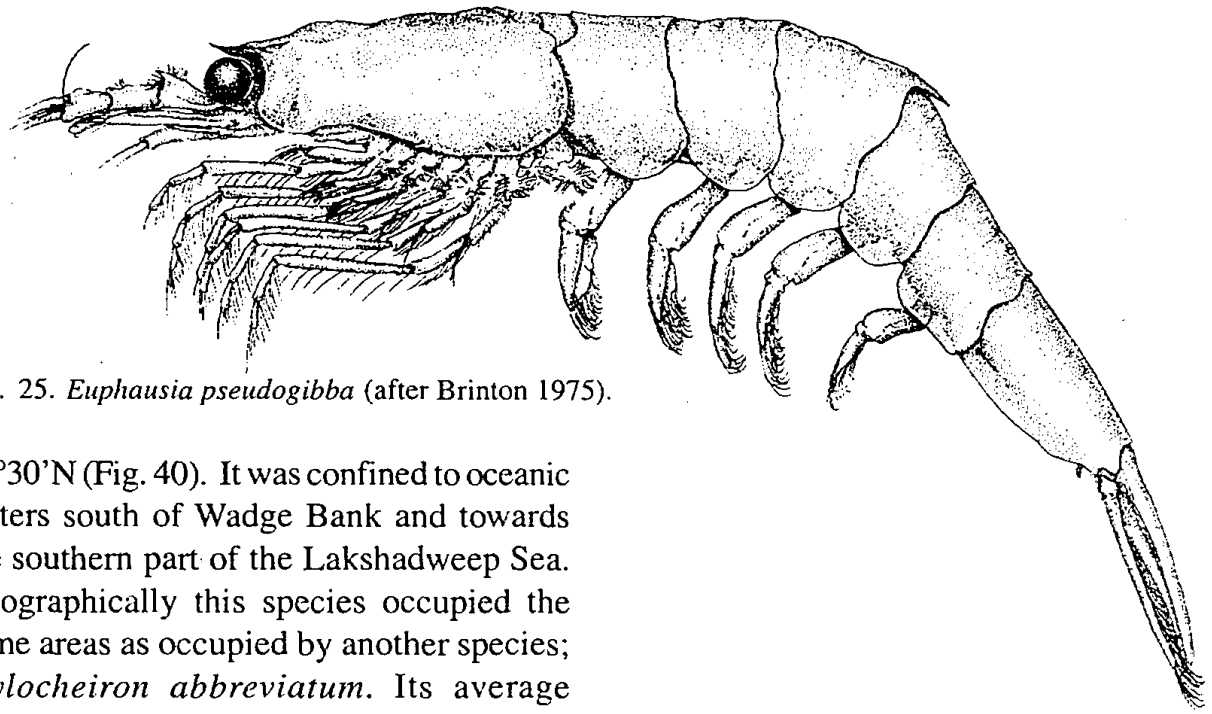

Fig. 25. *Euphausia pseudogibba* (after Brinton 1975).

Tattersall (1939) could find just seven specimens in four samples collected from the Maldive area. According to Ponomareva (1964) it was an abundant species in the Arabian Sea. Sebastian (1966) collected a few specimens from the southwest coast of India and Lakshadweep and Maldive areas. Gopalakrishnan and Brinton (1969) recorded it at three locations north of the equator. Another record from the Arabian Sea was by Weigman (1970). According to Brinton and Gopalakrishnan (1973) *E. pseudogibba* occurs in the latitudinal zone between 0° and 10°N. A few specimens were present in the samples studied by Mathew (1980e, 1982) and Silas and Mathew (1986) from the oceanic waters off the southwest coast of India upto 10°N.

Nematoscelis gracilis Hansen 1910 (Fig.26)

This epipelagic species is found throughout the equatorial zone of the world oceans. In the present investigation this was found distributed upto 19°N indicating widespread occurrence in the Arabian Sea (Fig. 27). Its average occurrence in the area was 309 per 1000 m^3 of water and it was the third abundant species. It was especially abundant south of 10°N. The species was mostly confined to areas beyond the continental shelf and was frequently caught in the Lakshadweep waters and south of the

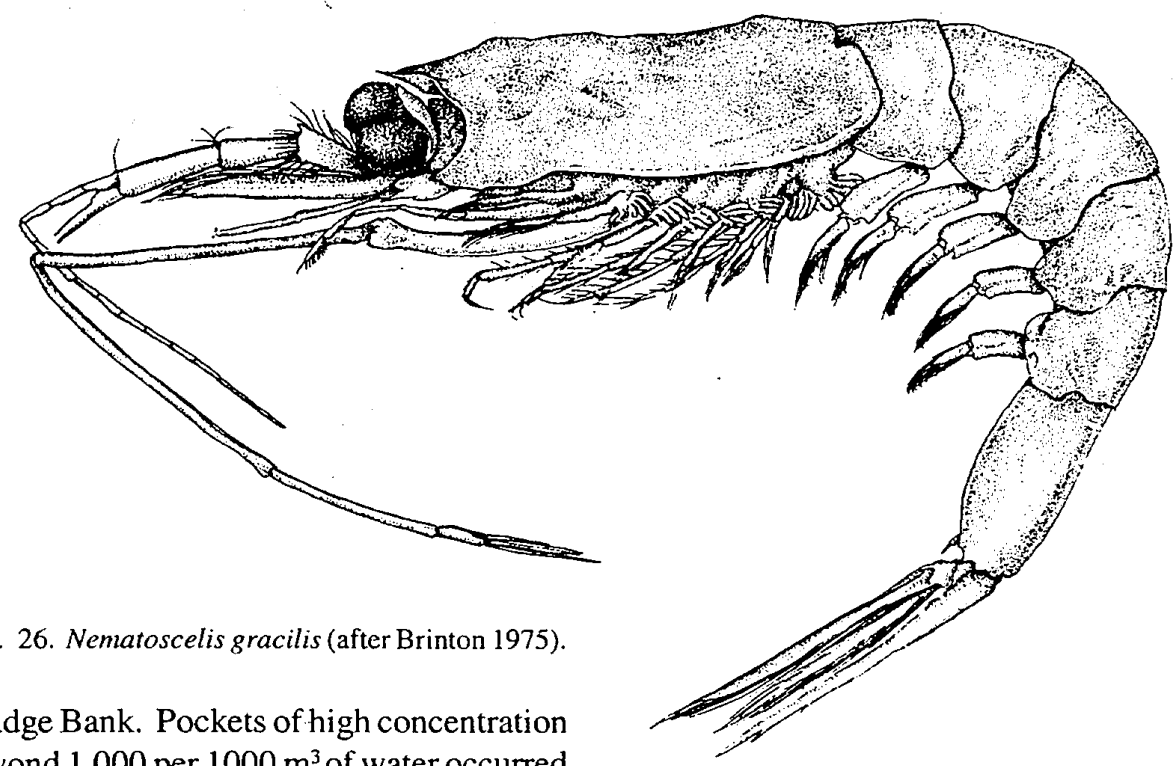

Fig. 26. *Nematoscelis gracilis* (after Brinton 1975).

Wadge Bank. Pockets of high concentration beyond 1,000 per 1000 m^3 of water occurred at several localities in the Lakshadweep waters. The population fluctuated between 4 and 9,675 per 1000 m^3 of water at various stations and the highest number was recorded in the oceanic Lakshadweep waters west of Cochin. The population from a high density in the southern areas thinned out as proceeded towards north.

N. gracilis was poorly represented in the collections obtained during the *Sea Lark* Expedition (Tattersall 1912). Illig (1930) reported good number of its specimens from the equatorial Indian Ocean. This was the characteristic species in the samples made during the *John Murray* expedition (Tattersall 1939) from Central and southern Arabian Sea and the Maldive waters. Ponomareva (1964) also reported it from the Arabian Sea. Sebastian (1966) obtained the species from the southwest coast, Lakshadweep and Maldive areas. Gopalakrishnan and Brinton (1969) observed it as one of the most abundant species in the equatorial Indian Ocean. Mathew (1980e, 1982) found the species moderately distributed in the shelf waters between 3 and 175 per 1000 m^3 of water. The northern limit according to him was 16°N which is now extended upto 19°N. He found the species to be mostly away from the continental shelf.

Nematobrachion flexipes Ortmann 1893 (Fig.28)

This epipelagic not so abundant species was found distributed in the oceanic waters limited to the southern part of the study area (Fig. 29). Its average population density in the area of occurrence was 55 per 1000 m^3 of water. The only two occasions

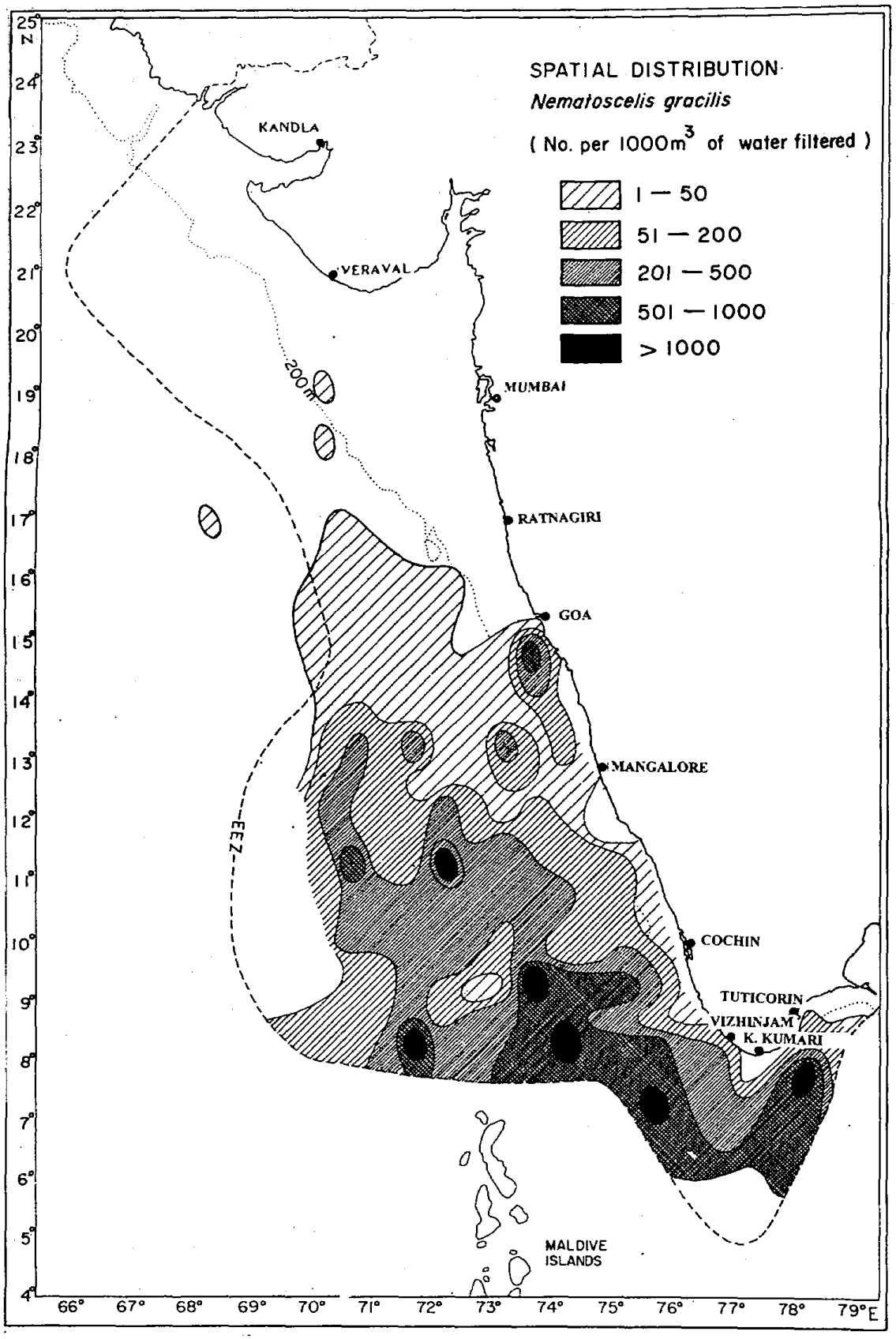

Fig. 27. Spatial distribution of *Nematoscelis gracilis* in the EEZ of the west coast of India.

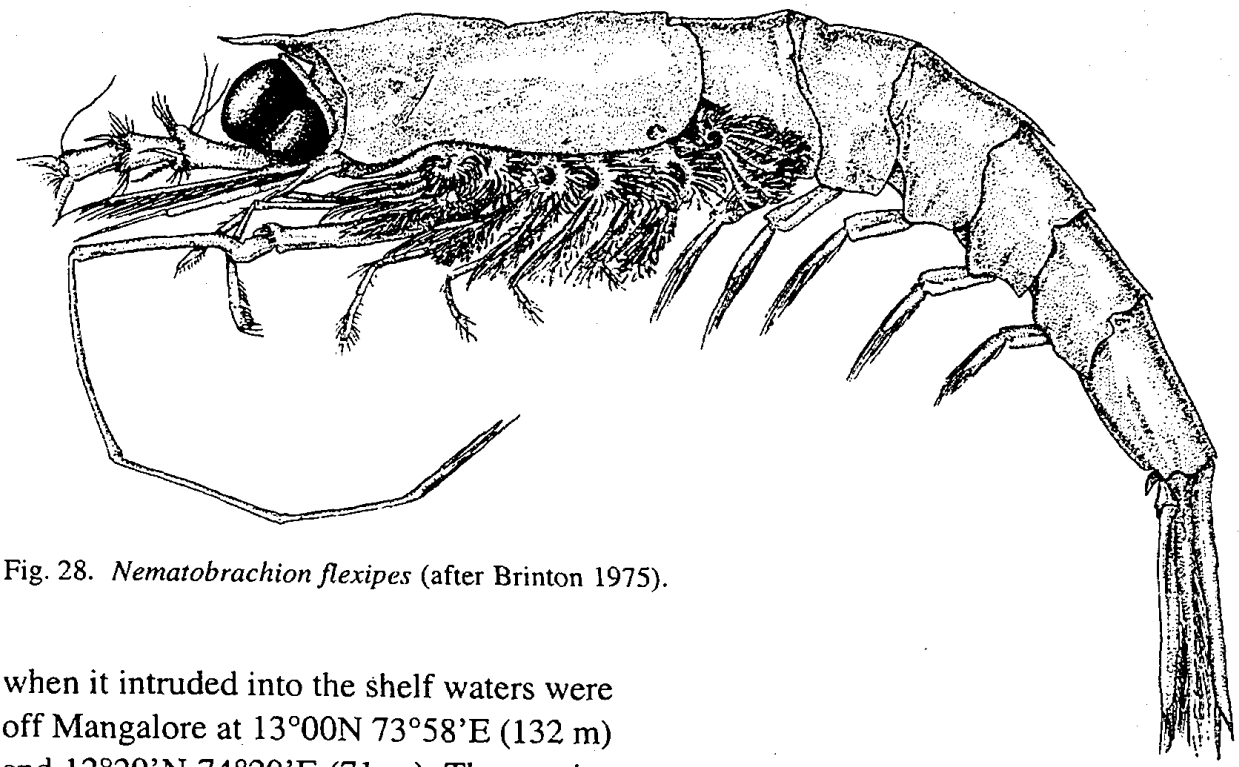

Fig. 28. *Nematobrachion flexipes* (after Brinton 1975).

when it intruded into the shelf waters were off Mangalore at 13°00N 73°58'E (132 m) and 12°29'N 74°20'E (71 m). The species was mostly represented south of 13°N but some stray occurrences were noticed upto 14°N. The pockets of high density were mostly south of 10°N. *N. flexipes* was comparatively more abundant off Cochin and nearer to the Lakshadweep islands. More than 100 specimens per 1000 m^3 of water were obtained on 9 occasions. The highest number of 419 per 1000 m^3 was recorded at 09°30'N 73°30'E in the Lakshadweep waters in April. The distribution of this species was somewhat patchy. Out of 493 samples analysed *N. flexipes* was present in 48 samples only.

N. flexipes though rare in occurrence is a widespread species in the Indian Ocean. Records have been made from several localities by many authors. Tattersall (1912) recorded it off Mauritius and off Nazarath Bank. Illig (1930) found it south of Sri Lanka and near Chagos. Ponomareva (1964) collected it from the Arabian Sea. The species was taken by Sebastian (1966) from the southwest coast of India and the Lakshadweep and Maldive waters. Gopalakrishnan and Brinton (1969) encountered it sparsely in the equatorial Indian Ocean. Brinton and Gopalakrishnan (1973) noticed it to be widely but irregularly distributed in the region between 15°N and 45°S in the Indian Ocean. Mathew (1980e & 1982) could not collect this species from the shelf waters along the southwest coast. However, from the oceanic waters he obtained this species at a rate of 1-7 per 1000 m^3 of water and extended the northern limit of the species in the Arabian Sea upto 16°20'N based on the deep water samples he examined.

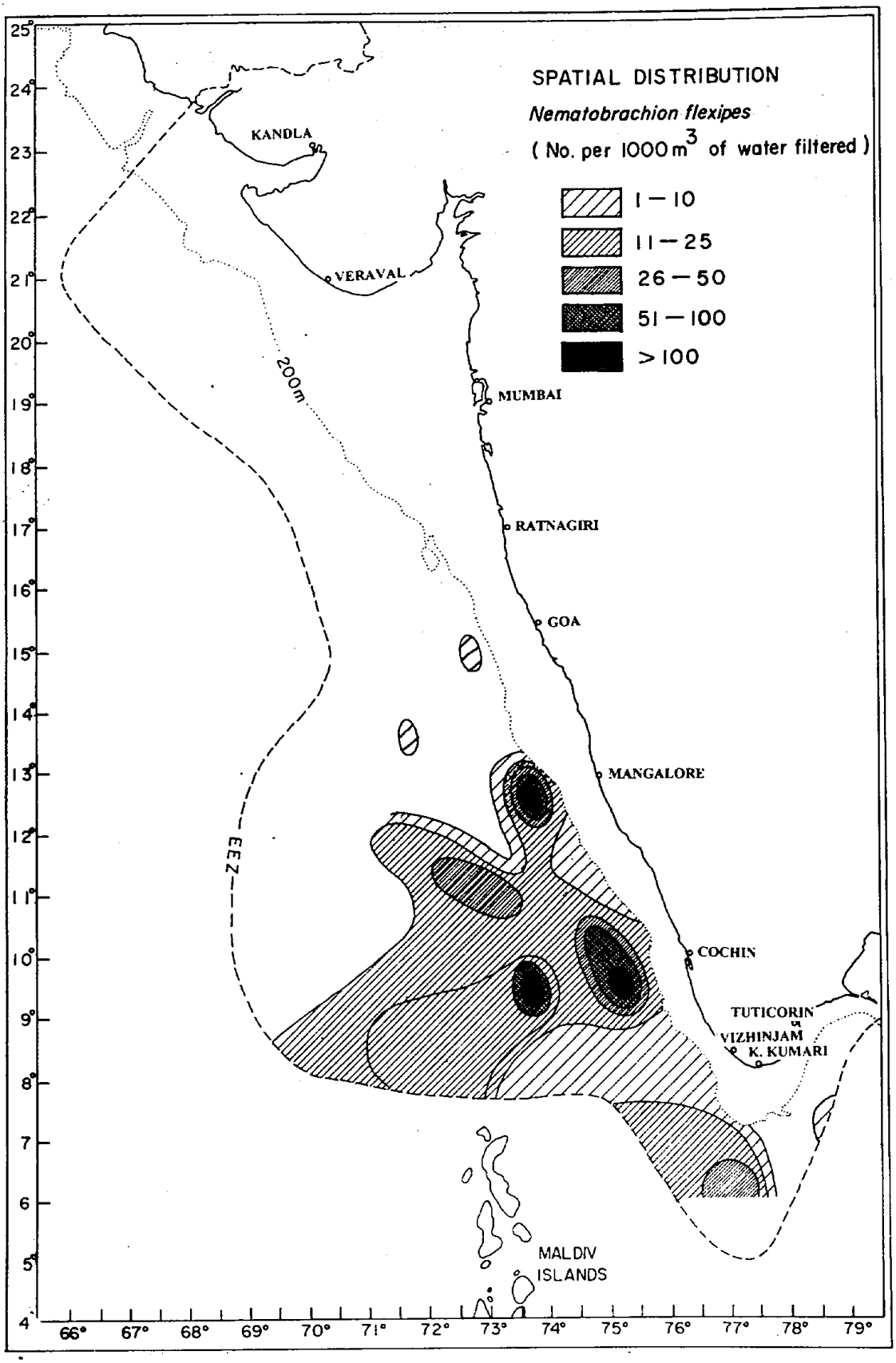

Fig. 29. Spatial distribution of *Nematobrachion flexipes* in the EEZ of the west coast of India.

Stylocheiron armatum Colosi 1917 (Fig.30)

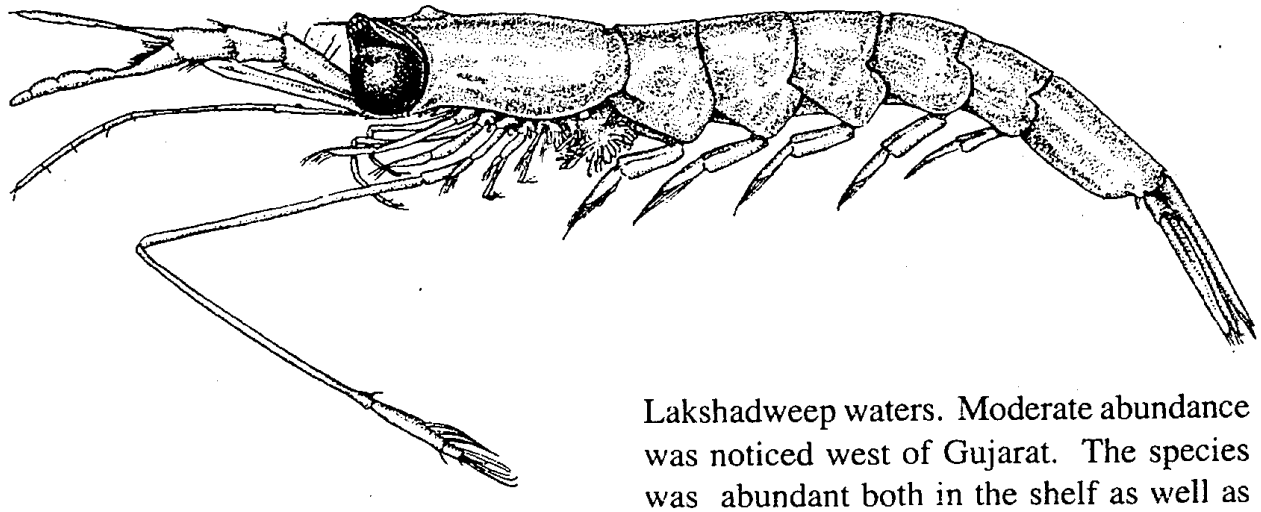

Fig. 30. *Stylocheiron armatum* (after Brinton 1975).

This species from the Arabian Sea was earlier considered as *S. carinatum*. However, studies conducted by Mathew (1980a, 1982) on the material from the southwest coast of India established that it belonged to *S. armatum* a species originally described by Colosi (1917) from the Red Sea and hence the population identified as *S. carinatum* in the Arabian Sea by the previous authors is considered here as *S. armatum*.

S. armatum is another epipelagic species occurring from the very surface to 700 m depth. It was present throughout the study area extending as north as 22°N and was the fifth species in the order of abundance Fig. 31). The average density of the population in the area was 230 per 1000 m^3 of water. As in the case of several other species its area of abundance was south of 12°30'N. *S. armatum* was especially abundant in the Lakshadweep waters. Areas of concentration beyond 1,000 per 1000 m^3 of water were found at several localities in the Lakshadweep waters. Moderate abundance was noticed west of Gujarat. The species was abundant both in the shelf as well as oceanic areas. The highest concentration of 3,592 specimens per 1000 m^3 of water was at a station west of Minicoy. Density of more than 1,000 per 1000 m^3 of water was observed at 32 localities within the EEZ.

Tattersall (1912) recorded *S. armatum* in small numbers from a number of localities in the northern Indian Ocean. Colosi (1917) identified a few specimens from the Arabian Sea along with a number of them from the Red Sea. Illig's (1930) records were from south of Sri Lanka, east of Maldives and further southward. Tattersall (1939) recorded *S. armatum* from the central and southern Arabian Sea and Maldive areas. Ponomareva (1964) recorded the species in the Arabian Sea. Sebastian (1966) found it to be one of the common species which exhibited shoaling behaviour during the breeding season in the southeastern Arabian Sea. This was one of the characteristic species caught from the equatorial Indian Ocean by Gopalakrishnan and Brinton (1969). Another record of the

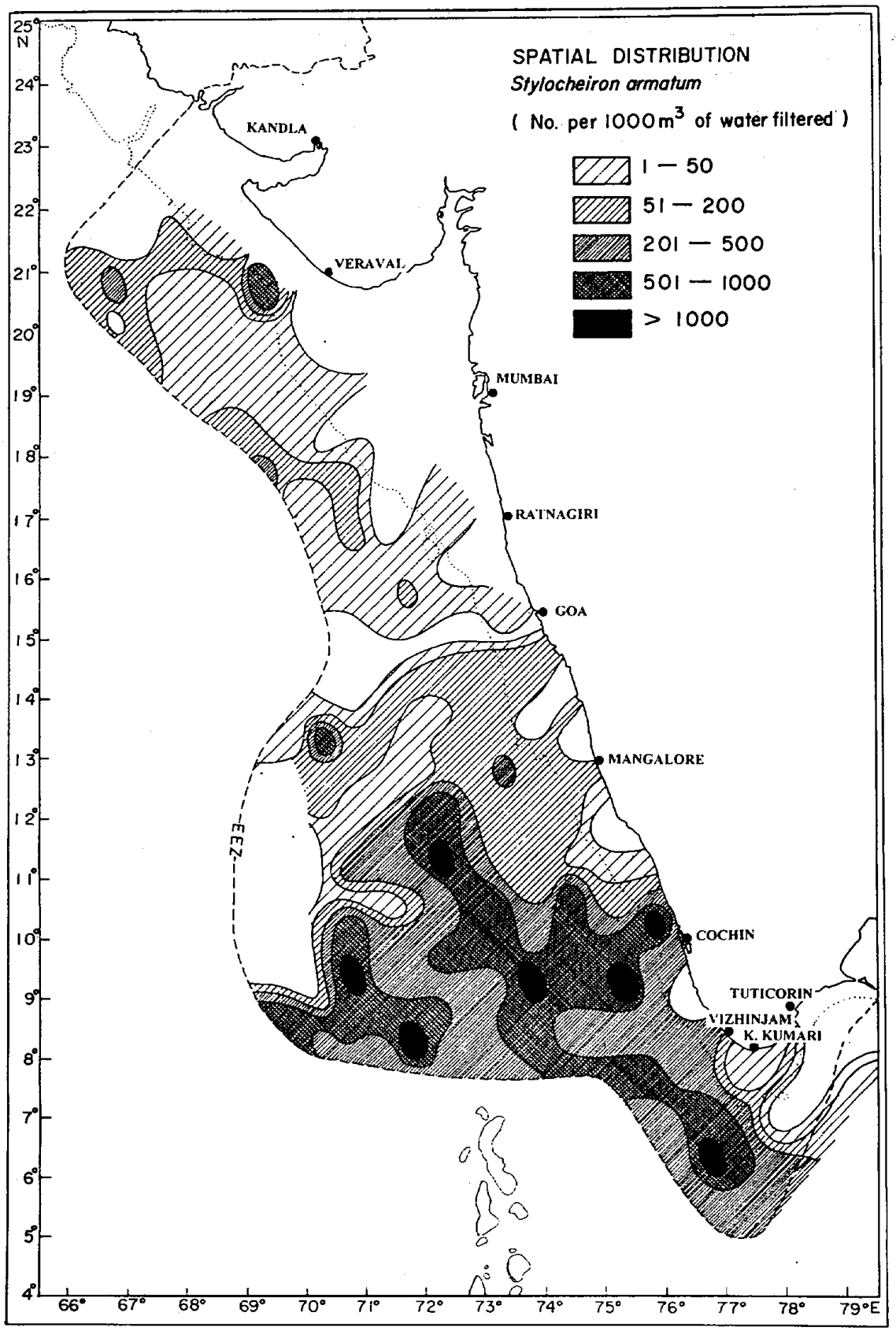

Fig. 31. Spatial distribution of *Stylocheiron armatum* in the EEZ of the west coast of India.

species from the Arabian Sea was by Weighman (1970). Brinton and Gopalakrishnan (1973) extended the northern distributional range up to the northern limit of the Indian Ocean. *S. armatum* was the second abundant species within the shelf area as found by Mathew (1980e, 1982) and Silas and Mathew (1986). Like *E. sibogae* it occurred in swarms occasionally forming patches of high density. In the oceanic area also Mathew (1982) found it to be one of the widespread and abundant species.

Stylocheiron affine Hansen 1910 (Fig.32)

This epipalagic species having a vertical range of 0-700 m found in the tropical and subtropical regions is one of the most abundant species in the EEZ of the west coast of India. In the study area it was found distributed far and wide from 05°30'N to 22°30'N and formed the sixth abundant species (Fig. 33). The average population density was 216 per 1000 m^3 of water. It was equally abundant in the shelf and oceanic waters. However, in areas north of Goa the species kept away from the shelf waters. Areas of high density beyond 500 per 1000 m^3 of water were observed at several places all along the coast. They were especially abundant southwest of Cochin, east of Minicoy, south and west of Goa, northwest of Mumbai and in the oceanic waters off southwest of Kandla. The highest density of 2,051 per1000 m^3 of water was recorded at 09°30'N 75°30'E southwest of Cochin. Specimens over 1,000 per 1000 m^3 of water were taken on seven occasions of which five were south of 9°N.

The previous investigators also indicated the widespread occurrence of *S. affine* in the Indian Ocean. It occurred throughout the course of *Valdivia* (Illig 1930). In 1939 Tattersall reported the species from the northern and the southern Arabian Sea and the Maldive areas. Ponomareva (1964)

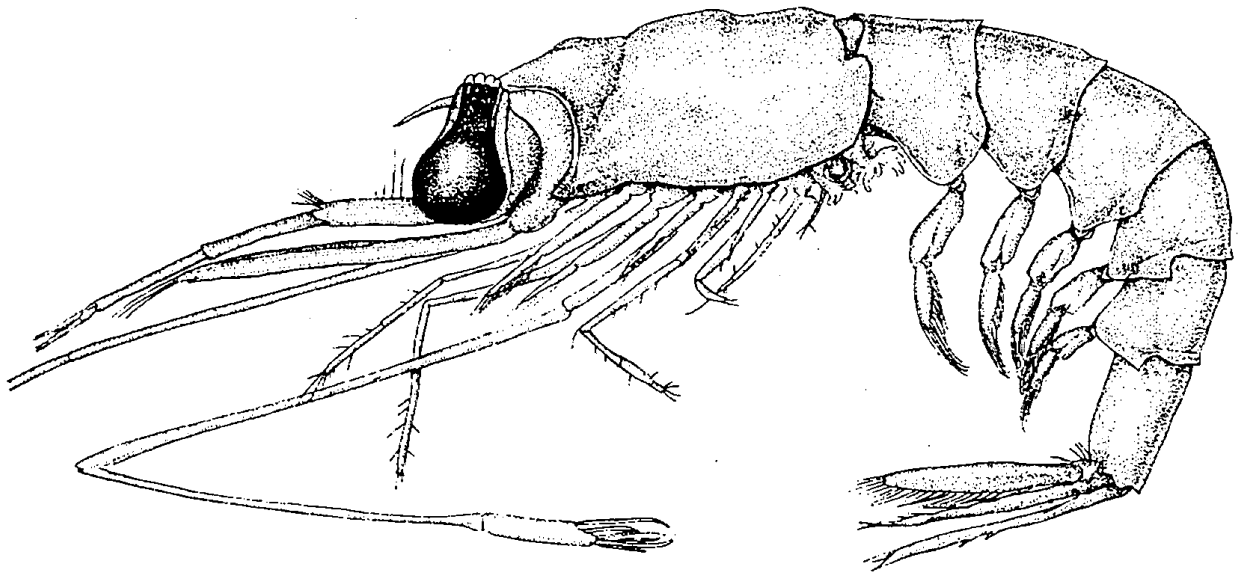

Fig. 32. *Stylocheiron affine* (after Brinton 1975).

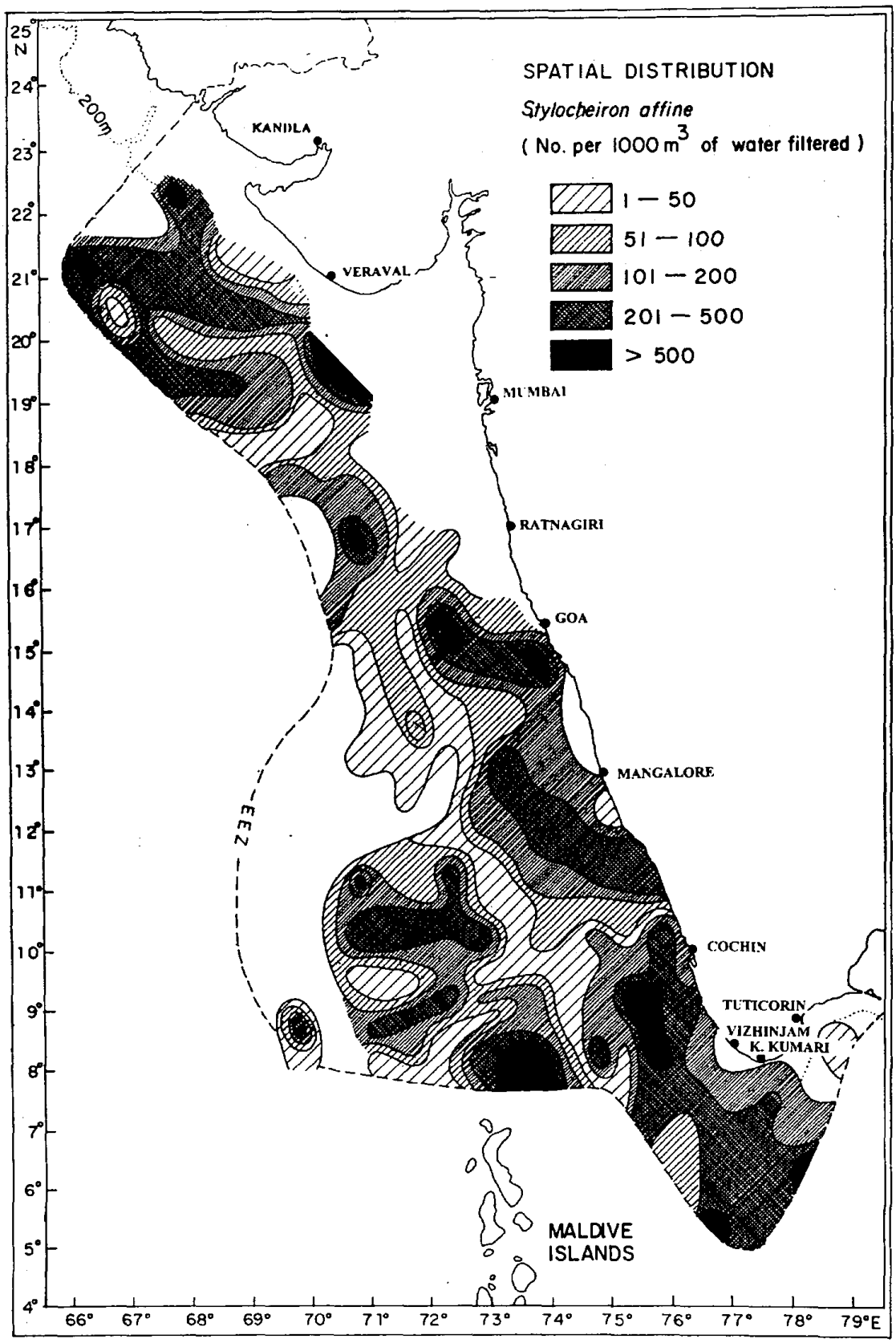

Fig. 33. Spatial distribution of *Stylocheiron affine* in the EEZ of the west coast of India.

recorded the species in the Arabian Sea. As observed by Sebastian (1966) it was a fairly common species of the southwest coast of India and the Lakshadweep and the Maldive seas. In the Red Sea *S. affine* was the second abundant species as found by Ponomareva (1968). In the equatorial Indian Ocean it was taken in small numbers only (Gopalakrishnan and Brinton 1969). Weighman (1970) also reported this species from the Arabian Sea. According to Brinton and Gopalakrishnan (1973) *S. affine* occurs from 35°S to the northern limit of the Indian Ocean. Mathew (1980e, 1982) and Silas and Mathew (1986) found this species widely and abundantly distributed in the shelf as well as oceanic waters.

Stylocheiron suhmii G.O. Sars 1883 (Fig.34)

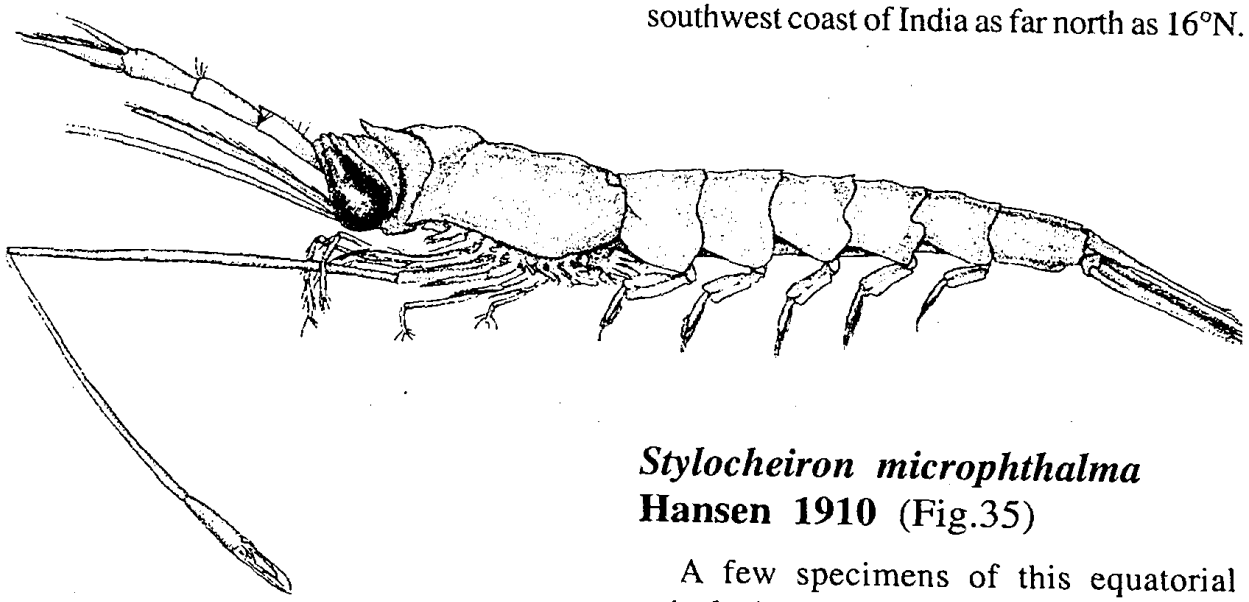

Fig. 34. *Stylocheiron suhmii* (after Brinton 1975).

This central epipelagic species occurring upto 700 m depth was occasionally taken from beyond the continental shelf edge south of 13°30'N. It was mostly confined to the continental shelf edge and the nearby oceanic waters (Fig. 40). The maximum number taken from a station was 32 per 1000 m^3 of water.

Tattersall (1912) found it to be widespread but sparse in the northern Indian Ocean. Illig (1930) reported it from several localities in the Indian Ocean including the Red Sea. Ponomareva (1964) and Weighman (1970) recorded it in the Arabian Sea. Gopalakrishnan and Brinton found it confined to the equatorial waters. Mathew (1980e, 1982) and Silas and Mathew (1986) collected a few specimens of this species from the shelf as well as oceanic areas of the southwest coast of India as far north as 16°N.

Stylocheiron microphthalma Hansen 1910 (Fig.35)

A few specimens of this equatorial epipelagic species having a vertical range of 0-280 m were taken from south of 10°N in the purely oceanic waters (Fig. 40). It was present mostly in the southern limit of the

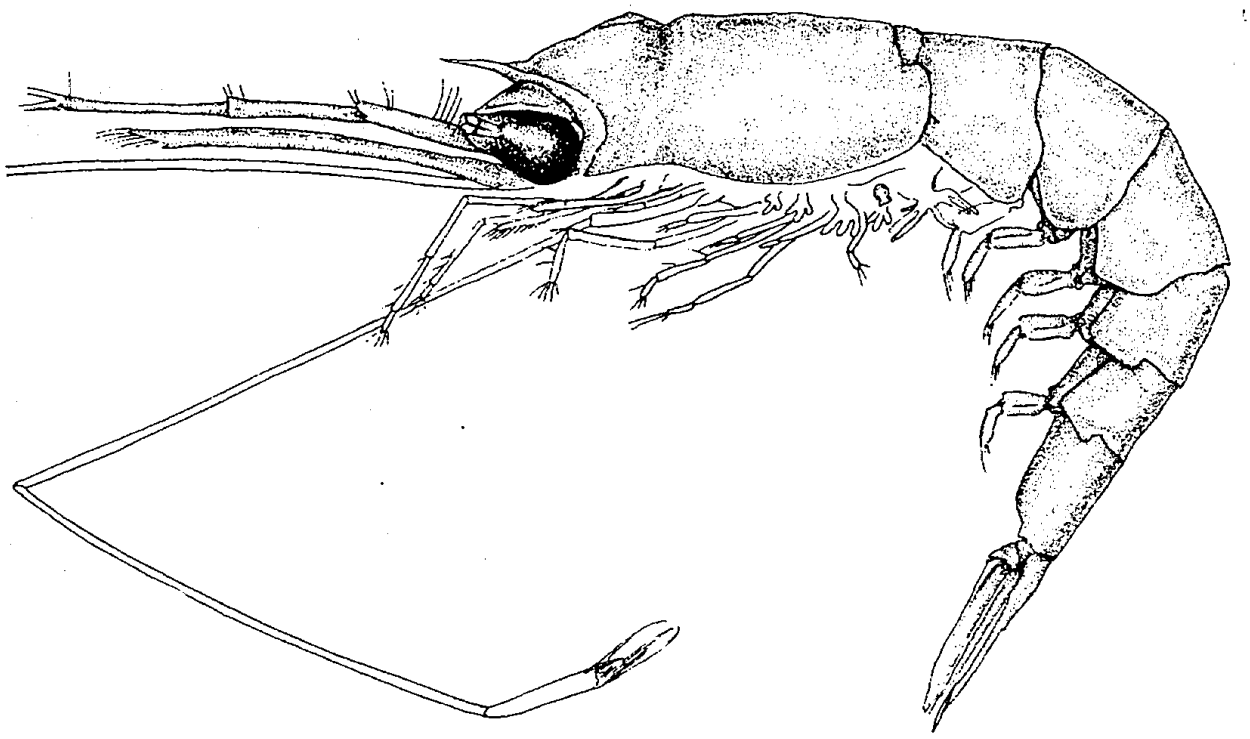

Fig. 35. *Stylocheiron microphthalma* (after Brinton 1975).

Lakshadweep and towards Maldive Islands. The maximum number occurred was 9 per 1000 m^3 of water.

Tattersall found it in the northern Indian Ocean south of equator. Ponomareva (1964) and Weigman (1970) recorded it from the Arabian Sea. Sebastian (1966) reported it from the Lakshadweep and Maldive waters. Gopalakrishnan and Brinton (1969) obtained it from the equatorial waters. According to Brinton and Gopalakrishnan (1973) the species was well represented south of 10N°. Mathew (1980e, 1982) and Silas and Mathew (1986) recorded *S. microphthalma* from a few locations along the southwest coast in the shelf edge and oceanic areas and it reached as far north as 10°40'N.

Stylocheiron longicorne (G.O. Sars 1883) (Fig.36)

This species is considered as central equatorial mesopelagic occupying a vertical range of 140-700 m. In the present studies the species was found strictly confined to the southern latitudes mostly south of 12°N and away from the continental shelf waters (Fig. 37). A few specimens occurred even north of this limit. Though widespread in occurrence it never appeared in large numbers, may be because the sampling was done in the epipelagic zone. The highest number taken was 545 per 1000 m^3 of water at 09°30'N 73°30'E in the Lakshadweep waters. Large concentrations were always found in the oceanic areas of the Lakshadweep.

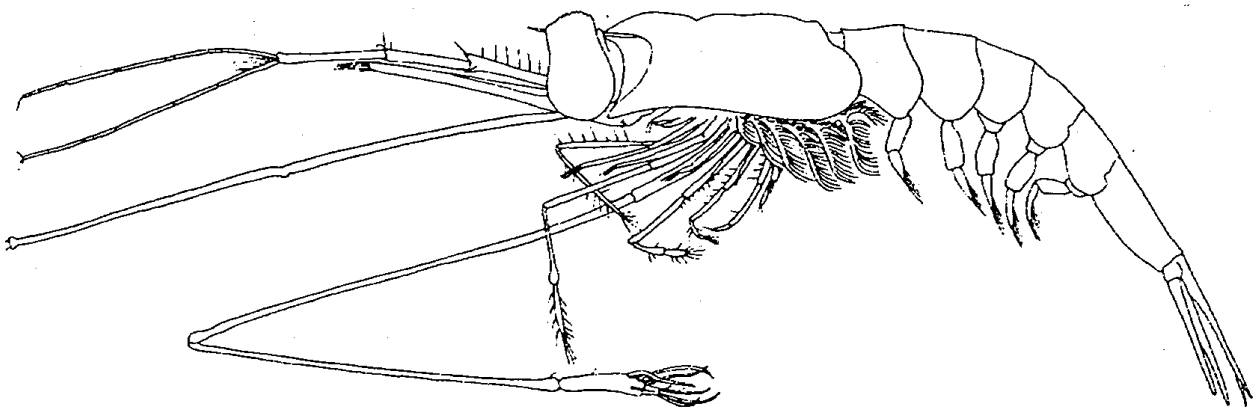

Fig. 36. *Stylocheiron longicorne* (after Brinton 1975).

Tattersall (1912) found *S. longicorne* fairly widespread but in low numbers in the western equatorial Indian Ocean. The species was found widely distributed during the *Valdivia* Expedition (Illig 1930) with the southern limit extending upto 34°14'S. Tattersall (1939) during the *John Murray* Expedition found it distributed in the northern, central and southern Arabian Sea and in the Maldive waters. Ponomareva (1964) made records of the species in the Arabian Sea. It was fairly common throughout the area investigated by Sebastian (1966). Smaller numbers were collected from the equatorial Indian Ocean during the *Luciad* Expedition (Gopalakrishnan and Brinton (1969). In 1970 Weighman reported the species from the Arabian Sea. According to Brinton and Gopalakrishnan (1975) it is a widely occurring species in the tropical Indian Ocean. Mathew (1980e, 1982) and Silas and Mathew (1986) obtained a few specimens from the shelf edge along the southwest coast of India.

Stylocheiron abbreviatum G.O. Sars 1883 (Fig.38)

This typically central epipelagic species moving down upto 700 m during a diurnal cycle was found confined to the oceanic area south of 10°N (Fig. 40). However, there were instances of the species moving upto 12° N. A few specimens were taken from between 10°30'N and 12°N on four occasions just outside the continental shelf limit. The species always occurred in small numbers; the highest number being 134 per 1000 m^3 of water from south of Wadge Bank.

Earlier records of *S. abbreviatum* show that the species extends its northern limit via the western Arabian Sea. It was frequently caught from the Red Sea and the Gulf of Aden by Torelli (1934a). During the *John Murray* Expedition a few specimens were collected from the Red Sea, central and southern Arabian Sea and the Maldive Sea. Ponomareva *et al.* (1962) also recorded it from the western Arabian Sea. Sebastian (1966) found it in the southeastern Arabian Sea. Ponomareva (1968) collected a few specimens from the Red Sea. It was regularly

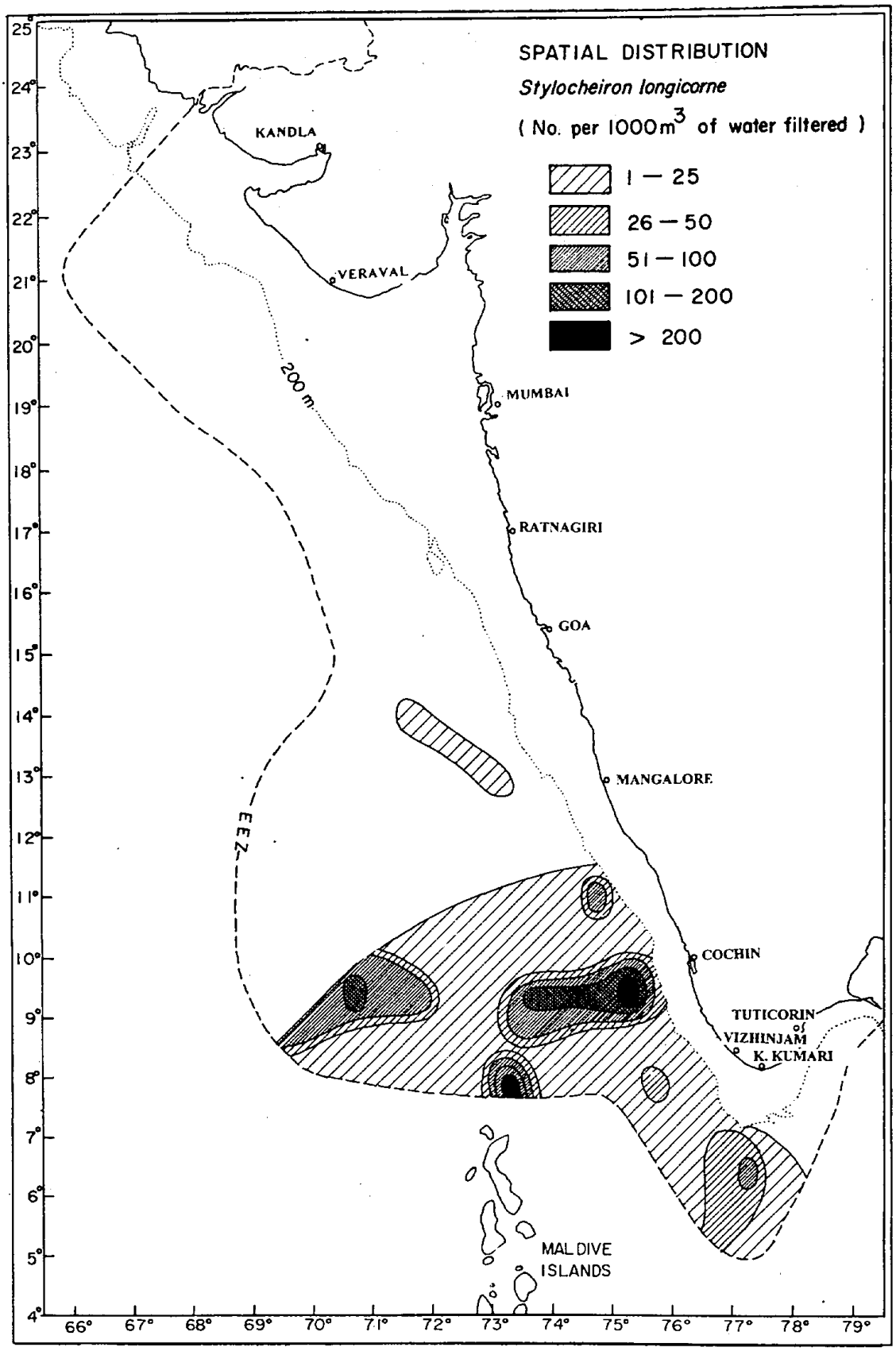

Fig. 37. Spatial distribution of *Stylocheiron longicorne* in the EEZ of the west coast of India.

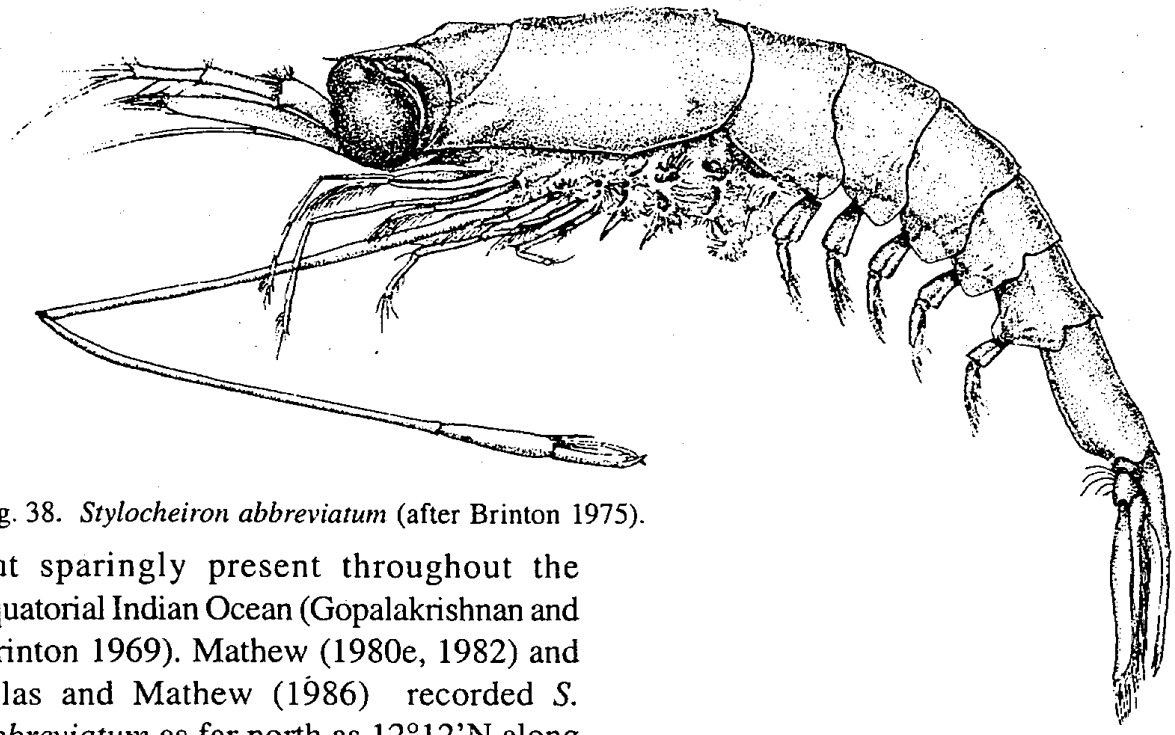

Fig. 38. *Stylocheiron abbreviatum* (after Brinton 1975).

but sparingly present throughout the equatorial Indian Ocean (Gopalakrishnan and Brinton 1969). Mathew (1980e, 1982) and Silas and Mathew (1986) recorded *S. abbreviatum* as far north as 12°12'N along the southwest coast. The trend of occurrence in their study area showed that it was not an abundant species but the presence of 275 adult specimens in a single haul with the IKM Trawl made them to conclude that it was not a rare species at least in the oceanic waters. According to them the capability of this carnivorous species to avoid the net might be one reason for their least capture.

Stylocheiron maximum **Hansen 1908** (Fig.39)

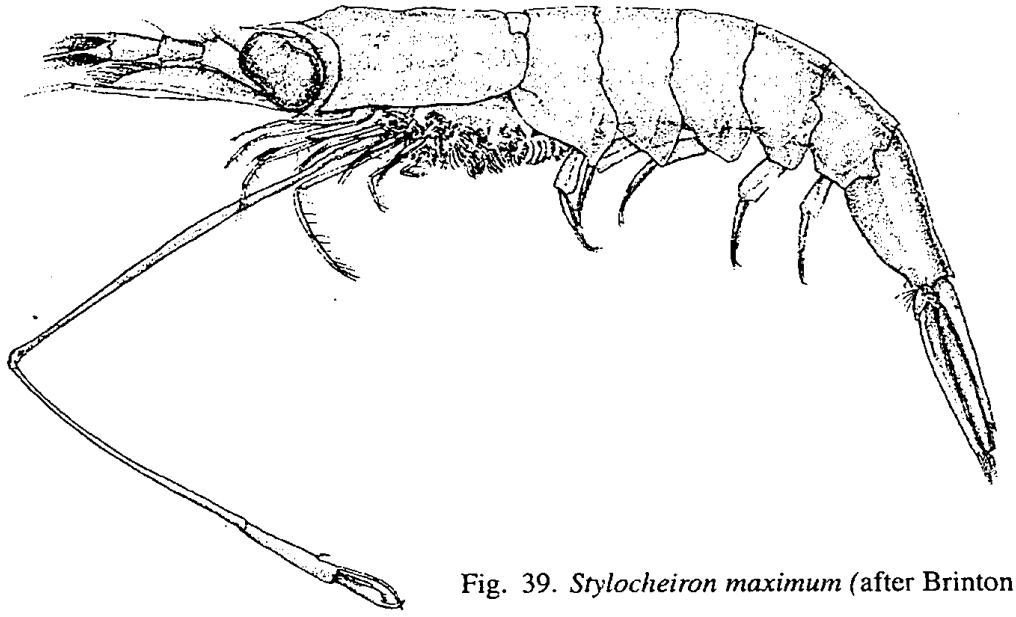

Fig. 39. *Stylocheiron maximum* (after Brinton 1975).

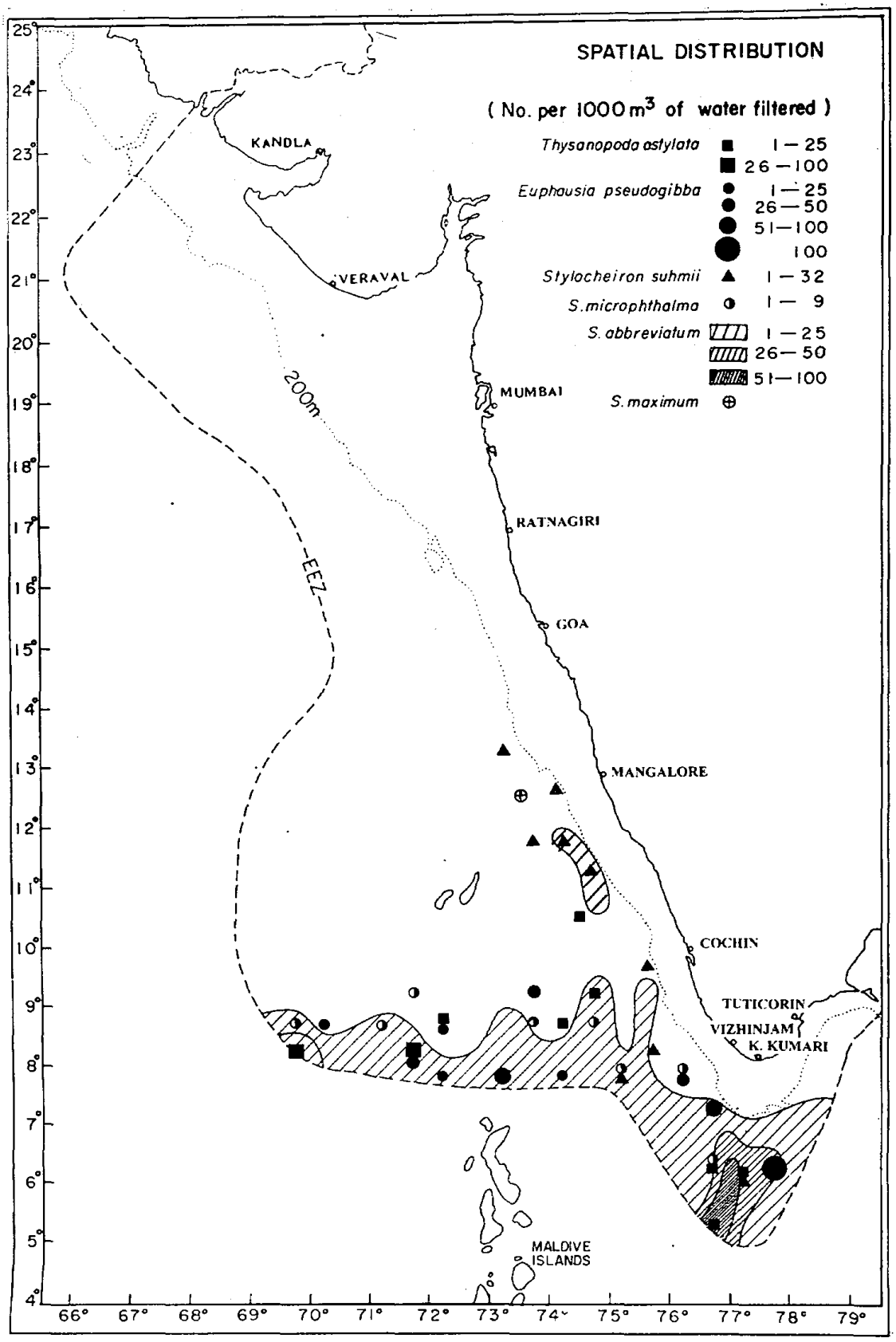

Fig. 40. Spatial distribution of *Thysanopoda astylata, Euphausia pseudogibba, Stylocheiron suhmii, S. microphthalma, S. abbreviatum* and *S. maximum* in the EEZ of the west coast of India.

Eventhough qualified as a mesopelagic cosmopolitan species, it was taken only once from a night station at 12°30'N 73°30'E southwest of Mangalore away from the continental slope where the depth to bottom measured 1960 m (Fig. 40). The rather shallow nature of sampling for the studies might have resulted in the poor capture of the species.

Other records from the Arabian Sea include that of Illig (1930) from southwest of Sri Lanka and from near Chagos. During the *John Murray* Expedition Tattersall (1939) collected it from the Central Arabian Sea. Ponomareva (1964) also took it from the Arabian Sea. Sebastian (1966) obtained a few immature specimens from the southeastern Arabian Sea. Ponomareva *et al.* (1962) reported the species from the Mumbai coast. Brinton and Gopalakrishnan (1973) found it to have a broad range of distribution in the Indian Ocean. Gopalakrishnan and Brinton (1969) obtained a few furcilia larvae from the equatorial Indian Ocean. Mathew (1980e, 1982) and Silas and Mathew (1986) recorded *S. maximum* at 10 locations along the southwest coast in the oceanic waters including one juvenile and a larva from the shelf edge station.