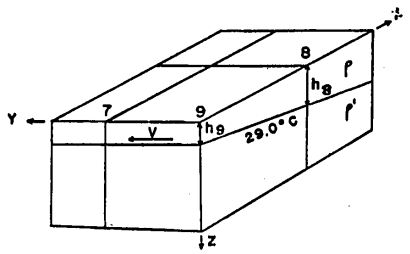

Fig. 7 Ideally simple model of two homogenous layers.

Imagine that the sea consists of two homogeneous layers, and the lower layer is at rest. The current v in the upper layer is assumed to be parallel to the y-axis of the coordinate system in Fig. 7. Then, from the consideration of the geostrophic balance, we can get the following relation:

$$f.v = (1 - \rho/\rho')\, g \frac{dh}{dx} \qquad (1)$$

where f is the Coriolis' factor and is expressed as $2\omega \sin\varphi$. his the thickness of the upper layer, and ρ and ρ' are the densities of the upper and lower layers respectively. On substitution of

$\rho = 1.0207\ g.cm^{-3}$, $\rho' = 1.0218\ g.cm^{-3}$,
$\Delta h = 8\ m$, $\Delta x = 110\ km$, $g = 980\ cm.sec^{-2}$,
$\omega = 7.292 \times 10^{-5}\ rad.sec^{-1}$, $\varphi = 6°30'N$,

into the above equation and calculating, we have

$v = 47.6\ cm.\ sec^{-1}$

In other words, there may be a southward-flowing current of about one knot along the east coast of the Malay Peninsula.

As mentioned before, this southward-flowing current was actually observed during a joint survey by Thailand, Malaysia and Germany (Anon., 1967). observation agrees with our results.

CONCLUSION

A narrow belt of southward-flowing current is considered to appear along the east coast of the Malay Peninsula during the northeast monsoon and its subsequent stagnant season. By this current the water of the Gulf of Thailand seems to be transported to the area off the east coast of the Peninsula.

References

Robinson, M. K. 1963. Physical oceanography in the Gulf of Thailand. Ecology of the Gulf of Thailand and the South China Sea, A report on the results of the Naga Expedition, 1959–1961: 34–50.

Anonymous 1967. Results of the joint Thai-Malaysian-German trawling survey off the east coast of the Malay Peninsula, 1967. Marine Fisheries Laboratory, Department of Fisheries, Ministry of Agriculture and Cooperatives, Thailand and Fisheries Research Institute, Fisheries Division, Ministry of Agriculture and Cooperaitves, Malaysia. 18 p. 1967.

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Preliminary Report on the Distribution of Chaetognaths in the Southern Part of the South China Sea

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Abstract

This paper reports the distribution of chaetognaths in the southern part of the South China Sea, based on the plankton samples collected by the research vessel CHANGI from April 1970 to April 1972.

The chaetognath specimens collected in April, 1972 were identified. Altogether 22 species belonging to 5 genera were discerned. *Sagitta enflata* was the dominant species and was widely distributed in the areas surveyed. While the common species in the neritic waters are *S. bedfordii*, S. bedoti, *and S. oceania*, the common species in the oceanic province are *Krohnitta pacifica, K. subtilis, Pterosagitta draco, S. bipunctata, S. hexaptera, S. lyra, S. minima, S. pacifica* and *S. regularis. S. enflata* and *S. ferox* are common in both neritic and oceanic provinces.

The individual numbers of chaetognaths varies from 400 to 13,000 per 100 m^3 of water. In general, the chaetognaths are abundant in coastal waters but decline towards the open sea.

Based on the occurrence of the various species, the importance of chaetognaths as biological indicators of water masses are discussed. *P. draco, S. hexaptera, S. minima* and *S. pacifica* are useful indicators of the presence of oceanic water in the neritic province. The presence of these species in some neritic waters adjacent to the oceanic province suggests the mixing of oceanic water and neritic water in the respective areas during the survey.

1. INTRODUCTION

Chaetognatha, a group of permanently planktonic invertebrates, is one of the dominant groups of zooplankton in the South China Sea. It is an important food item of some juvenile and plankton-feeding fishes. Certain species of Chaetognaths, such as *Sagitta setosa* and *S. elegans*, were reported to be associated with a more or less specific hydrographical environment, and thus are useful indicators of the movement of water masses (Fraser, 1952). Studies on this group of zooplankton is therefore a matter of particular importance.

In the Southeast Asian region studies on the Chaetognaths have been carried out mainly in the Gulf of Thailand (Alvarino, 1963, 1967), the waters off east coast of Vietnam (Alvarino, 1967; Hamon, 1956; Serene, 1937) and near Penang Island (Pathansali, 1968). Wickstead (1961) reported briefly on 10 species belonging to 3 genera in the Indo-West Pacific waters. No other data has hitherto been published on Chaetognatha in the southern parrt of the South China Sea.

Since 1970, oceanographic survey cruises have been carried out by the research vessel CHANGI of the Marine Fisheries Research Department, Southeast Asian Fisheries Development Center (SEAFDEC), in the southern part of the South China Sea, from 1°30'N to 10°20'N. This paper is a preliminary report on the rrsults of analysis on the distribution of Chaetognatha, based on the samples collected from April 1970 to April 1972. For the identification and occurrence of species, only the samples collected in April 1972 are dealt with.

2. MATERIALS AND METHODS

PLankton samples were collected by two vertical hauling at each station. Vertical hauling was made from 3 to 5 m above the sea floor or from a maximal depth of 150 m to the surface. The plankton net used was the North Pacific Standard Net with mesh size of 0.33 mm. The net was fitted with a flow-meter at the central part of the mouth to measure the total volume of water filtered through the net.

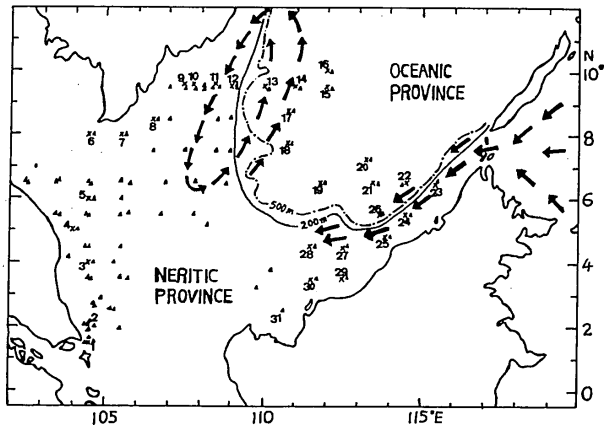

Fig. 1 Locations of sampling stations of CHANGI in 1970–1972.
X = sampling stations of the 1972 April cruise;
Δ = sampling stations of other cruises; the arrows indicate water movement as illustrated in the surface current chart for April by Naga Report (Wyrtki, 1961).

Plankton samples collected were preserved in 5% neutral formalin on board. In the laboratory all Chaetognaths were sorted from each sample and their individual numbers per cubic meter of water estimated.

The location of sampling stations are shown in Fig. 1. The surveyed areas are divided into 2 provinces, the neritic province (continental shelf area), and the oceanic province (area where the depth exceeds 200 m)

3. RESULTS

3.1 Species composition

A total of 22 species belonging to 5 genera were recorded. The list of species is shown below:

Genus *Eukrohnia* Ritter-Zahony
- *E. hamata* (Möbius) 1875

Genus *Krohnitta* Ritter-Zahony
- *K. pacifica* (Aida) 1897
- *K. subtilis* (Grassi) 1881

Genus *Pterosagitta* Costa
- *P. draco* Krohn 1853

Genus *Sagitta* Quoy and Gaimard
- *S. bedfordii* Doncaster 1903
- *S. bedoti* Beraneck, 1895
- *S. bipunctata* Quoy & Gaimard 1827
- *S. decipiens* Fowler 1905
- *S. enflata* Grassi 1881
- *S. ferox* Doncaster 1903
- *S. hexaptera* d'orbigny 1834
- *S. Iyra* Krohn 1853
- *S. minima* Grassi 1881
- *S. neglecta* Aida 1897
- *S. oceania* Grey 1930
- *S. pacifica* Tokioka 1940
- *S. pulchra* Doncaster 1903
- *S. regularis* Aida 1897
- *S. robusta* Doncaster 1903
- *S. septata* Doncaster 1903
- *S. zetesios* Fowler 1905

Genus *Spadella* Langerhans
- *Sp. cephaloptera* Grassi 1883

3.2 Occurrence

The occurrence of various species of Chaetognatha collected in April, 1972 is shown in Table I.

Alvariño (1967) recorded three species of the Genus *Eukrohnia* from the Naga collection. In the present collection, only one species of the genus, *E. hamata*, was found at two stations in the oceanic province. The other two species, *E. bathypelagica* Alvarino and *E. fowleri* Ritter-Zahony, were reported by Alvarió (1965) as mesoplanktonic plankton occurring in waters below 700 m.

Both species of the genus *Krohnitta* were found in the southern part of the South China Sea. *K. pacifica* appeared in most stations in the oceanic province and some stations in the neritic regions. It was more common than *K. subtilis*, the distribution of which was restricted to the oceanic province only.

Table I. Occurrence of various species of Chaetognatha in the southern part of the South China Sea during April, 1972*

Species \ Station no.	Neritic Province														Oceanic Province													Total no. of stations
	1	2	3	4	5	6	7	8	9	10	11	12	23	24	25	27	28	29	30	31	13	14	15	16	17	18	19	20	21	22	26	
E. hamata																							+	+								2
K. pacifica	+					+	+				+		+						+		+	+	+	+		+		+	+	+	+	15
K. subtilis																					+	+	+	+		+			+		+	7
P. draco												+	+								+	+	+	+		+		+	+	+	+	11
S. bedfordii	+	+	+	+	+	+		+	+						+	+	+	+	+	+												14
S. bedofi	+	+		+		+		+	+									+	+	+												9
S. bipunctata											+	+	+								+	+	+					+	+	+		9
S. decipiens																						+	+	+				+				4
S. enflata	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	31
S. ferox	+			+	+	+			+	+	+		+	+			+		+	+	+	+	+				+	+	+	+	+	20
S. hexaptera													+								+	+	+	+	+	+	+	+	+		+	11
S. lyra																					+	+	+	+		+	+			+		7
S. minima											+	+	+		+		+				+	+	+	+	+			+	+	+	+	14
S. neglecta			+		+		+	+	+	+	+	+									+	+										10
S. oceania	+			+	+	+		+	+	+	+		+	+	+	+	+	+	+													15
S. pacifica											+	+	+								+	+	+	+			+	+	+	+	+	12
S. pulchra												+									+	+									+	4
S. regularis						+	+	+			+	+									+	+	+	+	+	+	+					12
S. robusta						+		+			+	+	+	+		+					+	+			+					+	+	12
S. septata					+	+																										2
S. zetesios																						+		+								2
Sp. cephaloptera													+																			1
Total no. of species	6	3	3	5	6	9	4	7	6	4	10	9	11	4	4	4	5	4	6	4	14	16	13	12	5	7	6	9	9	9	10	

* '+' denotes the presence of the species in the station indicated.

P. draco, the single species of the genus *Pterosagitta*, was mainly in oceanic waters.

Altogether 17 species belonging to the genus *Sagitta* were collected. *S. enflata* distributed widely in all areas surveyed and in most cases, especially in inshore stations, it was the most dominant species of the Chaetognaths population. It has been reported to be also dominant in the Java Sea (Delsma n, 1939).

S. bedfordii, S. bedoti and *S. oceania* were common in the neritic province but were completely absent in the oceanic province. In contrast, *S. bipunctata S. hexaptera, S. lyra* and *S. pacificas,* were common in the oceanic province but were either absent or rare in the neritic province. This restricted distribution pattern indicates that the occurrency of these species is associated with specific hydrographical environment.

S. ferox, S. neglecta, S. regularis and *S. robusta* were found in both neritic and oceanic provinces. While *S. neglecta* was more common in the neritic province, *S. ferox, S. regularis* and *S. robusta* were found mostly in the oceanic province. Although *S. minima* also occurred in the oceanic province, it was more abundant in the neritic waters adjacent to oceanic province, in stations 11, 12, 23, 25 and 28.

S. decipiens and *S. pulchra* were not common in the present collections. *S. decipiens* was observed in 4 stations in the oceanic province while *S. pulchra* was observed in 3 stations in the oceanic province and one station in the neritic province adjacent to oceanic province. Both *S. septata* and *S. zetesios* were recorded intwo stations only; *S. septata* appeared in the neritic province and *S. zetesios* appeared in the oceanic province.

Sp. cephaloptera is the only species of the genus *Spadella* recorded in the samples studied. It is a benthic species (Alvarino, 1965) and was obtained in station 23.

According to the number of stations from which the various species of Chaetognaths were collected, the common species are as follows:

Neritic and oceanic provinces: *S. enflata* and *S. ferox*
Neritic province: *S. bedfordii, S. bedoti,* and *S. oceania*
Oceanic province: *K. pacifica, K. subtilis, P. draco, S. bipunctata, S. hexaptera, S. lyra, S. minima, S. pacifica* and *S. regularis.*

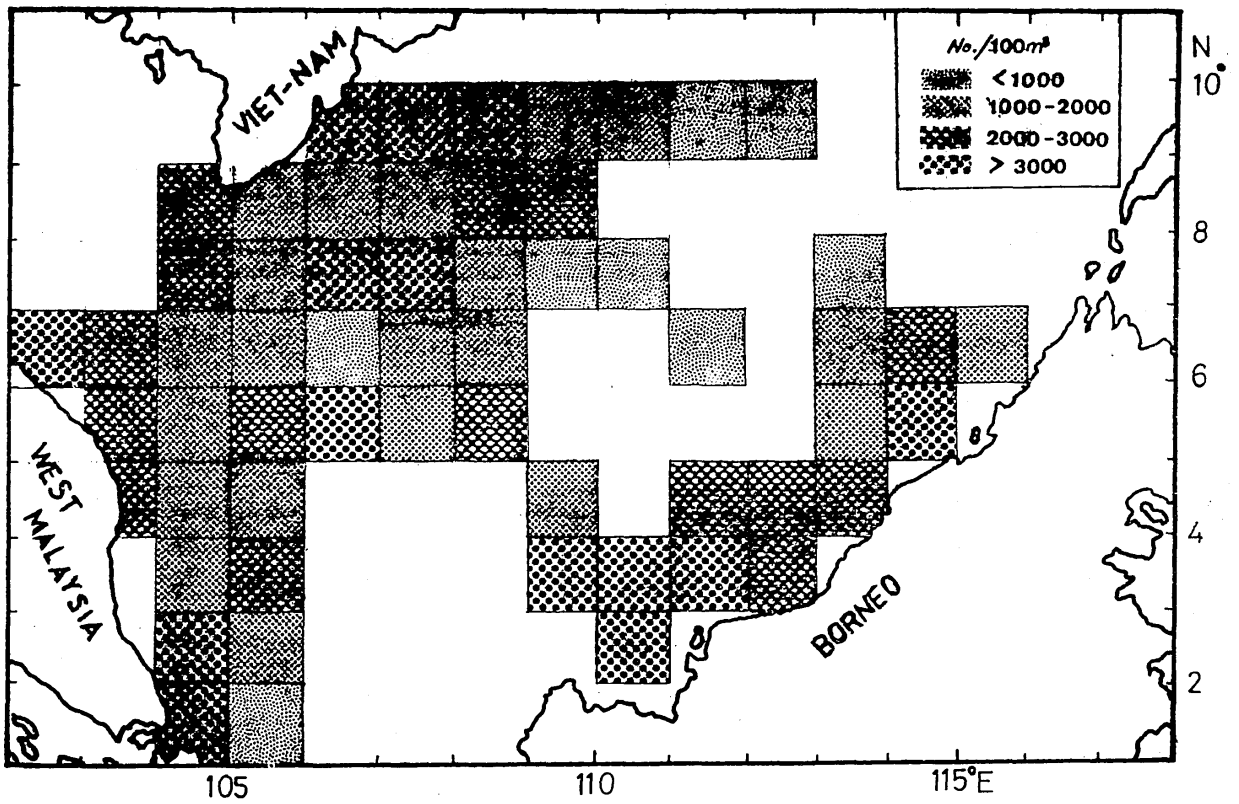

Fig. 2 Quantitative distribution of Chaetognatha in the South China Sea (1970–1972)

3.3 Quantitative distribution

Fig. 2 shows the quantitative distribution of chaetognaths in the southern part of the South China Sea, 1970–72. The abundance of chaetognaths is represented in a block of 1 sq. degree (60 x 60 mile^2) When there are more than one station in the same block, only the average values of individual numbers of the respective stations are shown.

The individual numbers of chaetognaths in the southern part of the South China Sea varies from 400 to 13,000 per 100 m^3 water. High numbers of chaetognaths were sampled in areas near Singapore, the Gulf of Thailand, off Vietnam, the northwest coast of Borneo and in some offshore areas of the Continental Shelf.

Chaetognatha was abundant in coastal areas but decreased towards offshore waters. This phenomenon is more obvious in the area along 6°30'N and 9°30'N. As shown in Table II, the individual numbers of chaetognaths were highest in near-shore stations and decreased towards the open seas.

Table II. Quantitative distribution of Chaetognatha (No./100m^3) in relation to the distance from shore.

Along 6°30'N (June 1971)	Longitude	102°30'E	103°30'E	104°30'E	105°30'E	
	Distance (ml.)	30	30	150	210	
	Number	6,100	1,600	1,590	1,300	
Along 9°30'N (September 1971)	Longitude	106°50'E	107°30'E	108°00'E	108°30'E	109°00'E
	Distance (ml.)	40	80	110	140	170
	Number	13,000	9,700	7,480	3,500	1,220
Along 9°30'N (April 1972)	Longitude	108°00'E	109°00'E	110°00'E	111°00'E	112°00'E
	Distance (ml.)	110	170	230	290	350
	Number	2,550	1,860	1,600	600	590

4. DISCUSSION

The distribution of plankton is dependent on its physiological adaptation to the environment and on the water movement. Thus, any water mass may have, to some extent, its own characteristic plankton.

Different types of water may often be clearly defined by their planktonic communities or at least by certain of their plankton species (Alvarino, 1965). Of the 22 species of chaetognaths collected by CHANGI in April 1972, some species were found to be common in one province but rare or completely absent in another. Such a pattern of distribution indicates that the occurrence of the respective species may be associated with environmental factors. As mentioned above, *K. subtilis* and *S. lyra* were found only in the oceanic province while *S. bedfordii* and *S. oceania* were common in neritic waters. Thus, they can be considered as typical oceanic plankton and neritic plankton respectively. Other species such as *P. draco, S. hexaptera, S. pacifica* and the less common species of *E. hamata* and *S. decipiens,* found mainly in oceanic waters, may be grouped as oceanic type. Although *P. draco, S. hexaptera* and *S. pacifica* were essentially oceanic species, they were also observed in the neritic waters (stations 11, 12 and 23) adjacent to the oceanic province. This may suggest that mixing of oceanic and neritic waters may occur in these areas.

S. minima, a common species in the oceanic province, was found to be more abundant in the neritic waters adjacent to the oceanic province, (stations 11, 12, 23, 25 and 28). Alvariño (1965) regarded it as an oceanic epiplanktonic species, typical in regions where the mixing of waters occurred. Thus, the presence of *S. minima* in the neritic waters adjacent to the oceanic province further demonstrates that there was mixing of oceanic and neritic waters in the respective areas during the survey.

From the discussion made so far, it may be concluded that *P. draco, S. hexaptera, S. minima* and *S. pacifica* could be regarded as biological indicators of the presence of oceanic waters in the neritic province.

According to the Naga Report and the surface current chart (Wyrtki, 1961) a belt of oceanic water, originated from Sulu Sea, flows through Balabac strait into the South China Sea. As shown in Fig. 1, sampling stations 23, 25 and 28 of the CHANGI survey cruise in April 1972 were located along this belt. This may explain the presence of some oceanic chaetognaths species in the neritic waters. As for stations 11 and 12, the mixing of oceanic and neritic waters could be due to the circular current movement in the area as illustrated in the current chart of the Naga Report.

The present analysis shows that chaetognaths are abundant in the coastal areas but decrease towards offshore waters. As reported by Shirota et al. (1972), high plankton biomass is mainly confined in the ocastal areas of the South China Sea. Since chaetognaths are plankton-feeders, their abundance recorded in inshore waters could be attributed to the high productivity there. On the other hand, their abundant occurrence in certain offshore areas of the continental shelf may be due to the effect of boundary zone or current rip formed in the adjacent waters of the sampling stations as indicated in the summarized charts o the Naga Report (Wyrtki, 1961).

References

Alvarino, A. 1963. Chaetognatha, Siphonophorae and Medusae in the Gulf of Siam and the South China Sea. A Report on the Results of the Naga Expedition, 1959–1961. Scripps Institution of Oceanography, S 10–Ref. 63-6: 104–112.

Alvarino, A. 1965, Chaetognatha. pp 115–194 in Oceanography and Marine Biology, Vol. 3, 421 p. (H. Barnes, ed.) London, George Allen S. Unwin. 3:115–194.

Alvarino, A. 1967. The Chaetognatha of the Naga Expedition (1959–1961) in the South China Sea and the Gulf of Thailand. Scripps Institution of Oceanography. 197 p.

Delsman, H. Co., 1939. Preliminary plankton investigations in the Java Sea. *Treubia*, 17:139–181.

Fraser, J. H., 1952. The Chaetognatha and other Zooplankton of the Scottish Area and their value as Biological Indicators of Hydrographical Conditions. Edinburgh, Her Majesty's Stationery Office. 52 p.

Hamon, M. 1956. Chaetognathes recueillis dans la Baie de Nhatrang-Cauda (Viet-Nam). Bull. Mus. Hist. Nat., Paris, 28(5):466–473.

Pathansali, D., 1968. Some observations on the distribution of Chaetognatha west of Penang Island. Publ. Seto Mar. Biol. Lab., XV(5):391–397.

Serene, R. 1937. Inventaire des invertebrates marins de L'Indochine (Ire. liste). *Inst. Oceanog. Nhatrang,* 30:30.

Shirota, A., L. C. Lim and M. Chow. 1972. Some oceanographic characteristics of the southern part of the South China Sea. IPFC Sym. paper, 72/SYM41:1–11.

Wickstead, J. H., 1961. A Quantitative and Qualitative Study of Some Indo-West-Pacific Plankton, London, Her Majesty's Stationery OFFICE 200P'

Wyrtki, K., 1961 Physical Oceanography of Southeast Asian Waters. Naga Report, Vol. 2. Scripps Institution of Oceanography. 195 p.