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THE BIOLOGY OF CHAETOGNATHA IN THE BERING SEA AND THE NORTHERN NORTH PACIFIC OCEAN, WITH EMPHASIS ON *SAGITTA ELEGANS*[*]

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Contents

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I. Introduction

Chaetognaths (Phylum Chaetognatha) are carnivorous marine zooplankton which have a practically world-wide distribution. About 60 species have been reported from the world oceans (Tokioka, 1965a; Alvariño, 1967b). Most of them are known to be useful as an index of the character or origin of the water masses in the sea (Huntsman, 1919; Russell, 1932b; Tokioka, 1940a, 1959; Sund, 1959a; Bieri, 1959; LeBrasseur, 1959; Kitou, 1966a; Marumo, 1966; Kotori and Hara, 1972, etc.). The body of the fully matured animals is elongated torpedo-like in shape, with head, trunk, and tail regions. They dart about, like arrows in the water, so that they are commonly called arrow worms, and the principal genus of the animals is named *Sagitta* (L., arrow). Almost all living chaetognaths are transparent, and some of the species become opaque when they are fixed with formalin-seawater. Being transparent, they are also called glass worms. The phylum name refers to the bristles (hooks) about the mouth (Gr., *chaeton*, bristle; *gnathos*, jaws).

All species belonging to this phylum are hermaphrodites which possess not only ovaries on their trunk but also testes on the tail region. Chaetognaths are euplanktonic animals except the species referring to the genus *Spadella* which lives in shallow neritic waters, often clinging to rocks and algae by adhesive papillae near the tail (John, 1933). The size of the matured chaetognaths varies with the species from about 5 to over 90 mm long (Tokioka, 1940a; David, 1955; Alvariño, 1962), so that the animal group belongs to macroplankton in the marine environment. Chaetognaths are ordinarily second in abundance to copepods in offshore seas (Ryther, 1969; Reeve, 1970a). The biomass of chaetognaths compared to the total mass of zooplankton, in wet weight, occupies approximately 10% in the oceanic waters averaging from epipelagic to bathypelagic domains in the northern North Pacific Ocean and the Bering Sea in summer (Kotori, 1972). In the upper 500 m in the Sargasso Sea near Bermuda, the fraction is about 15% of the total zooplankton weight (Menzel and Ryther, 1961 Ms., cited from Beers, 1964). Furthermore, observations on the nature of the food of chaetognaths based on gut contents of preserved or freshly-caught material indicated that they were voracious carnivores. They have most frequently been observed to take copepods, as well as euphausiids, amphipods, fish larvae and other prey animals (Lebour, 1922, 1923; David, 1955; Murakami, 1959; Della Croce, 1963; Reeve, 1970a; Takano, 1971; Reeve and Walter, 1972; Nagasawa and Marumo, 1972; Pearre, 1973). On the other hand, chaetognaths are known to be prey organisms for some fishes and other carnivores (David, 1955; Wickstead, 1962; Inoue et al., 1967; Rakusa-Suszczewski, 1968; Angel, 1970; Kubota, 1971; Takeuchi, 1972; Sekiguchi et al., 1974). Therefore, chaetognaths should be situated ecologically between the secondary and higher trophic levels in the food webs of the sea.

In the present studies some biological aspects of chaetognaths in the Bering Sea and the northern North Pacific Ocean were investigated in an attempt to ascertain the hypothesis that the chaetognaths are situated ecologically between the secondary and higher trophic levels, playing an important rôle in the food webs in the sea: in the first place the areal and vertical distribution of chaetognath species in the actual area in summer was observed quantitatively, and the relationship between the distribution and its limiting factors was discussed; secondarily the developmental processes of *Sagitta elegans* Verrill, which were suggested to be the most dominant chaetognath in the upper 150 m deep in the present area, were examined, and the rates of respiration in this species were determined; and finally the rôle played by a chaetognath community in the upper 150 m deep was discussed, our study being based on the calculation of carbon requirement of the community in the Bering Sea in summer.

II. Previous work

Until today chaetognaths have been considered to be taxonomically similar to the cases of the other zooplankton groups. Regular taxonomical studies on chaetognaths were started in the latter part of the nineteenth century. In Japan, Aida (1897) examined chaetognaths and reported 12 chaetognath species from the materials collected in Misaki Harbor. The monographic work by Ritter-Záhony (1911) may be regarded as the base for the taxonomy of this phylum which has been accepted so far. Other important and well-known contributors to the taxonomy of the animal group may be listed as follows: Fowler (1905, 1906), Michael (1911), Huntsman (1919), Grey (1930), Thiel (1938), Tokioka (1939, 1940a, b, 1957, 1959, 1965a, b), Lea (1955), David (1958), Sund (1959a, b), Alvariño (1962, 1967b), Kitou (1966c), Marumo and Kitou (1966), Dawson (1968), Park (1970), and so forth. However, the affinities of this phylum and the phylogenetic position of the chaetognath species are still obscure. Tokioka (1965b) suggested that the position and length of corona ciliata and the relative length of the tail region will be keys to the discussion on the phylogeny of chaetognath species. Ghirardelli (1968) suggested that chaetognaths have similarities in morphological characteristics to annelids and nematodes rather than to other animal groups, although the morphological differencies among these phyla are not less important for us to determine the affinities of chaetognaths.

One of the main objects of the plankton studies is to disclose the principles which underlie the distribution of the oceanic organisms. One method of approaching the problems is to work out as fully as possible the zoogeographical distribution of a number of species. Fowler (1906) is one of the representative investigators who actively engaged in the zoogeography of chaetognaths in the first two decades of our own century. He described, not only taxonomically but also zoogeographically, 10 species referring to 3 genera of chaetognaths from the samples collected during the Siboga cruise to the North Pacific Ocean, the South Pacific Ocean, and the Indian Ocean. Huntsman (1919) observed the vertical and horizontal distribution of 10 species of the animal group collected off the Canadian Eastern Coast in the North Atlantic Ocean. He pointed out that chaetognaths were very prominent in the zooplankton catches, sometimes forming more than half of the entire catch, and that their distribution would depend upon temperature, salinity, light, oxygen, currents, and food. Michael (1911) investigated the vertical distribution of chaetognath species off San Diego in the North Pacific Ocean. He (1919) also examined the distribution of the animal group collected in the western North Pacific Ocean during the Philippine Expedition by the U.S. Steamer "Albatross."

It appears quite reasonable that such contributions to the zoogeography on chaetognaths, as described above, aroused deeper interest in the study on the animal group during the twenties and thirties of this century: Lebour (1922, 1923) examined the food of plankton organisms including chaetognaths; Russell (1932a, b, 1933a, b) rigidly investigated the breeding, growth, and natural history of *Sagitta elegans* and *S. setosa* in the Plymouth area; and Thiel (1938) made such accurate and extensive observations on the distribution of chaetognaths and water temperature in the Atlantic Ocean as that he found that *Eukrohnia hamata* is to be a cold-water cosmopolite occurring frequently in the high-arctic part of the Norwegian Sea, off northwestern Greenland and Spitsbergen, commonly in low arctic, temperate, and tropical latitudes in the Atlantic, although in small numbers, in deeper water, and abundantly again south of the tropical zone with the maximum in shallow water. This becomes the accepted theory as to the cause of other cold-water zooplankton migration to the deep water in low latitudes.

Accordingly, the biological studies on chaetognaths were diversified into several fields dealing with life history of a species, the relationship between the distribution of the species and its environmental factors, abundance, food habits, and other behavior of the animal: Parry (1944) anatomically investigated the function of the gut of *Spadella cephaloptera* and *Sagitta setosa*; David (1955) reported such biological problems as distribution, life history, and gut contents of *S. gazellae*; Murakami (1959, 1966) was first to rear *Sagitta crassa* successfully in the laboratory for as long as three months in maximum to examine its endurance to changing temperature and chlorinity, developments in the early stages of its life span, and so on; Owre (1960) studied the relative abundance of species, the seasonal variation in abundance and the vertical distribution, and the breeding periods of chaetognaths collected off Miami in the Atlantic Ocean; Dunbar (1962) indicated that *S. elegans arctica* Aurivillius, a cold-water variant of *S. elegans* Verrill, of the Canadian eastern Arctic water has a life span of two years; the prey-predator relationship in the plankton community through chaetognaths were qualitatively observed by Della Croce (1963), who illustrated *Sagitta* attacking copepods, thaliaceans and chaetognaths, or being attacked by a copepod *Candacia*; Sherman and Schaner (1968) suggested that *Sagitta elegans* breeds once annually in the coastal waters of the Gulf of Maine facing the northern North Atlantic Ocean; and experiments made by Horridge (1966) and Horridge and Boulton (1967) in *Spadella cephaloptera* showed an accurate feeding movement toward any source vibrating at 9–20 Hz with an amplitude of 100–500 μm at a distance of 1–3 mm.

The scientific knowledge on the distribution and abundance of chaetognaths has been largely accumulated by several workers especially after the fifties. For instance, Chindonova (1955) observed the vertical distribution of 7 chaetognath species including *Heterokrohnia mirabilis*, which had been supposed to be endemic in the Antarctic Ocean, by hauls to depths of 6,000 m. David (1958) showed that the maximum concentrations of the five most common species of *Sagitta* are either vertically or horizontally separated in the Antarctic Ocean. Bieri (1959) clearly indicated the geographic extents of 27 species of chaetognaths in the Pacific Ocean in relation to the water masses. Tokioka (1959) also made such careful taxonomical observations on the animal group collected in the North Pacific Ocean and adjacent seas as to discuss the relationship between zoogeographical distribution of the species and the water masses. Dawson (1968) observed 4 species of chaetognaths in the Arctic Ocean and found the seasonal changes in the vertical distribution of the maturity stages of *Eukrohnia hamata*. The vertical distribution of chaetognaths in the Pacific Ocean was also laboriously studied by Furuhashi (1953, 1961), Hida and King (1955), Marumo et al. (1958), Alvariño (1962, 1964, 1967a), Kitou (1963, 1966a, b, c, d, 1967a), Vinogradov (1968), Kotori (1969, 1972), Fagetti (1972), and so forth, after the fifties.

These contributions to the biology of chaetognaths described above have given the animal group a position of primary carnivores, respecting its world-wide distribution, abundance, and food habits, among the marine macrozooplankton. This awoke so much interest among the marine ecologists that they began the study of feeding, respiration, excretion, nutrition, chemical composition of the body, and reproduction of the animals to determine the rôle played by chaetognaths in the marine environment by means of rearing them in the laboratory (Murakami, 1959, 1966; Beers, 1964, 1966; Reeve, 1964, 1966, 1970a, b; Reeve et al., 1970; Ikeda, 1970, 1972, 1974; Takano, 1971; Reeve and Walter, 1972; Sameoto, 1971, 1972; Pearre, 1973; Cosper and Reeve, 1975; Reeve et al. 1975; Kotori, 1975a, b; Reeve and Cosper, in press).

The biology of chaetognaths was reviewed by Ghirardelli (1968), who gave special attention to the biology of reproduction and to some organs and functions that had not been previously studied. A review on studies of chaetognaths in general, up to the early sixties, was also presented by Alvariño (1965).

III. Distribution and abundance of chaetognaths in the Bering Sea and the northern North Pacific Ocean

The distribution of chaetognaths in the Bering Sea and the northern North Pacific Ocean was investigated by several workers (Chindonova, 1955; Lea, 1955; Marumo et al., 1958; Sund, 1959a; LeBrasseur, 1959; Bieri, 1959; Tokioka, 1959; Alvariño, 1962, 1964; Kitou, 1966d, 1967a, b; Kotori, 1969, 1972; Kotori and Hara, 1972). However, more detailed observations for many samples collected through the vast areas of the seas are needed in order to make clear the distribution and abundance of chaetognaths in whole parts and depths of the Bering Sea and in the northern North Pacific Ocean.

A large number of zooplankton samples were collected by vertical hauls of 0 to 150-m with Norpac nets during the cruises of the T.S. "Oshoro Maru," Hokkaido University, to the Bering Sea and the northern North Pacific Ocean every summer since 1955. In addition, samples were accumulated by simultaneous horizontal tows with several closing nets.

This chapter deals with more detailed and comparable information on the abundance of chaetognaths and their areal and vertical distribution in the actual area to relate their environment.

1. Materials and methods

Cruises and stations: The twelve sea trips during which the present samples were obtained include 3 cruises of the T.S. "Oshoro Maru II" of the Faculty of Fisheries, Hokkaido University, in 1957, 1959 and 1960, one cruise of her successor the T.S. "Oshoro Maru III" in 1968, and one cruise of the R.V. "Hakuhō Maru" of the Ocean Research Institute, University of Tokyo in 1969. During the four "Oshoro Maru" cruises, zooplankton samples were collected with a North Pacific standard net (Norpac net, 45–cm mouth diameter, 180–cm side length, Motoda, 1957, 1961) at a total of 168 stations distributed over almost the whole area of the Bering Sea and the northern North Pacific Ocean, and during the "Hakuhō Maru"

Table 1. *Areas, number of stations at which plankton sampling was carried out, and related data on the cruises of T.S. "Oshoro Maru" of Hokkaido University and R.V. "Hakuhō Maru" of the University of Tokyo in the Bering Sea and northern North Pacific Ocean.*

Vessel, cruise number	Area	Number of station	Period	Reference
Oshoro Maru II, 39B	Northwestern North Pacific	19	Aug.-Sept., 1957	Fac. Fish. Hokkaido Univ., 1959
44	Northwestern North Pacific	24	June-July, 1959	Fac. Fish., Hokkaido Univ., 1960
	Western parts of the Bering Sea	17	June-July, 1959	Fac. Fish., Hokkaido Univ., 1960
46	Northwestern North Pacific	6	June, 1960	Fac. Fish. Hokkaido Univ., 1961
	Western parts of the Bering Sea	10	June, 1960	Fac. Fish., Hokkaido Univ., 1961
	South of Aleutian Islands	10	June, 1960	Fac. Fish., Hokkaido Univ., 1961
	Eastern parts of the Bering Sea	17	June-July, 1960	Fac. Fish., Hokkaido Univ., 1961
	Gulf of Alaska	7	July, 1960	Fac. Fish., Hokkaido Univ., 1961
	Northeastern North Pacific	3	Aug., 1960	Fac. Fish., Hokkaido Univ., 1961
Oshoro Maru III, 28	Eastern parts of the Bering Sea	47	June-Aug., 1968	Fac. Fish., Hokkaido Univ., 1969
	Off the southern coast of Alaska	8	July, 1968	Fac. Fish., Hokkaido Univ., 1969
Hakuhō Maru, KH–69–4	Northeastern North Pacific	4	Aug.-Sept., 1969	Marumo, 1970 ed.

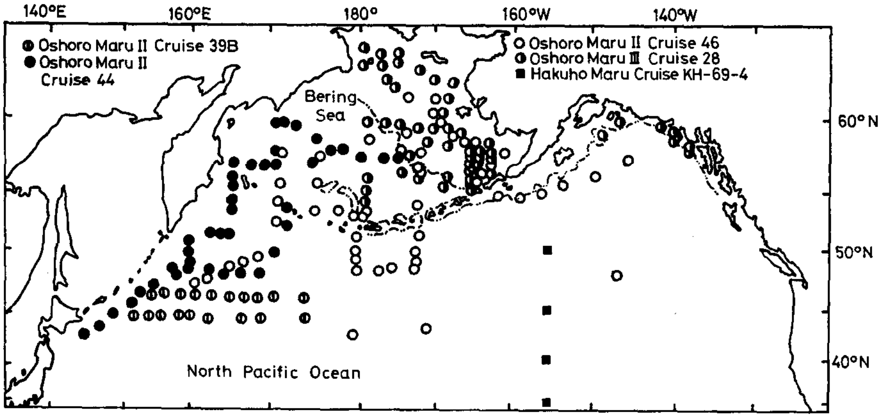

Fig. 1. Map showing the location of the sampling stations.

cruise, samples were obtained by simultaneous horizontal tows with nine or ten closing nets (MTD 56-cm net, Motoda, 1969) distributed from the surface to a depth of about 700 m at 4 stations in the northern North Pacific Ocean (Table 1).

Norpac net samples: One sample was collected at each station, and is shown in Appendix IA and Fig. 1, so a total of 168 Norpac net samples was collected and used in the present study. The samples were obtained mostly by vertical hauls, from a depth of 150 m to the surface, but sometimes from the near sea bottom to the surface when the bottom was shallower than 150 m.

The nets used in 1957, 1959 and 1960 were made of Japanese silk bolting cloth GG 54 (0.33-mm mesh aperture); those used in 1968 were made of pylen No. 60 (0.35-mm mesh aperture). However, the difference in catch efficiency between bolting silk net and pylen net was found to be insignificant (Morioka, 1965).

All samples were fixed in a 10% neutral formalin sea water solution. The total wet weight of the samples was measured immediately on board after removing large organisms such as shrimps, jellyfish, etc. (Fac. Fish., Hokkaido Univ., 1959, 1960, 1961, 1969). In the laboratory, the chaetognaths were separated. Species were identified and counted under a microscope. Then, the total wet weight of chaetognaths was measured by species. The results are given in Appendix IA-B. A flow meter attached to the center of the mouth ring of the nets recorded the water volume filtered, so that the biomass or individual number of the zooplankton and chaetognaths was expressed as g wet weight/1,000 m^3 or individuals/1,000 m^3 water filtered.

MTD 56-cm net samples: The samples in the present study were collected at 4 stations (Stas. KH691-KH694, Appendix II and Fig. 1) located on Long. 155° W from Lat. 50° to 35°N on the Cruise KH-69-4 of the "Hakuhō Maru" in the northern summer of 1969 (Motoda and Kotori, 1970). Six series of sampling were collected by simultaneous horizontal tows with nine or ten closing nets attached to a single cable. The nets made of pylen No. 60 (0.35-mm mesh aperture) were conical, 56 cm in diameter, 150 cm in side length, and fixed to triangular frames.

The depths of collection were estimated from the wire angle. The volume of water filtered in the hauls was computed from an experimented mean value of 394 m^3/hr. Two series of sampling were made at Sta. KH691 during daytime and at night from the 23rd to the 25th of August, 1969; one series at Sta. KH692 during daytime on the 29th of August; two series at Sta. KH693 during daytime and at night from the 31st of August to the 1st of September; and one series at Sta. KH694 during daytime on the 6th September, only a surface sample of which was examined in the present study, as Sta. KH694 was not situated in the Subarctic Water but in the Western North Pacific Central Water (Marumo, 1970 ed.). Accordingly, a total of 46 MTD 56-cm net samples was used in the present study.

The procedure for the samples in the laboratory and the one for the Norpac net samples are much similar, but the species were identified and counted in subsamples obtained by using a plankton splitter (Motoda, 1959), because the amount of a MTD 56-cm net sample is very large.

Data processing: In the present study zooplankton collectings with a Norpac net were all made in the northern summer. However, the samples were not collected in one year but in four different years as mentioned above. Therefore, the author is afraid the comparison of abundance of the animals in the whole area as shown in the present study would be impossible if the yearly variations of abundance of the chaetognaths were larger than the areal variations of abundance in the summer only. Table 2 gives the variabilities and means of chaetognath biomass (g wet weight/1,000 m^3) collected at the same locations in the Bering Sea in different months and years. It appears that all of the mean values of biomass collected on the going and returning trips in 1968 and the value in 1960 were not so different. The difference in the mean biomass of chaetognaths in the area between 1960 and 1968 was about 5-10%. However, the values observed individually at stations located even in approximately the same area occupied by a vessel during the period of a few days apparently varies from one to three orders of magnitude (e.g. 3.6-183.8 g wet weight/1,000 m^3 through Stas. 682830, 32-37, 39 and 40 from 23 to 26 June 1968, Table 2). Motoda and Anraku (1955), making

Table 2. *Variabilities and means of the chaetognath biomass (g wet weight per 1,000 m^3) collected with a Norpac net at the same locations in the Bering Sea in different months and years.*

No. of station	682830, 32-37, 39, 40 (9 stas.)	682860-64 (5 stas.)	604634-40 (7 stas.)
Date	June 23-26, 1968	July 26-27, 1968	July 6-11, 1960
Temperature (°C)	3.7-7.5	10.2-12.8	3.7-7.7
Salinity (‰)	31.37-32.03	31.80-32.02	31.56-32.07
Chaetognath biomass (g/1000 m^3)			
Range	3.6-183.8	1.9-87.3	17.2-151.0
Mean	60.3	50.8	65.2

a series of five replicate hauls from a depth of 150 m to the surface with a Standard Marutoku Net (45 cm in mouth diameter, 100 cm in side length, 0.327-mm mesh aperture), pointed out that the percentage of standard deviation of a single observation of the net was 47%, and the 95% fiducial limits are 46% and 217%.

Consequently, the variance in abundance of the samples collected in the present area was expressed by using such major scales as "more than 10,000," "9,999-5,000," "4,999-2,000," "1,999-1,000," "999-500," "499-1," and "0" individuals/1,000 m^3, and the minor variances in abundance were neglected so as to illustrate the areal distribution of chaetognaths.

All samples collected by vertical hauls from 150-m depth to the surface with a Norpac net at the daytime and night stations (a total of 168 stations) were compared with each other irrespective of the time of collection because the range of diel vertical migration of *Sagitta elegans*, the predominant chaetognath in the epipelagic domain, is likely to be 0–150 m, and because *Eukrohnia hamata*, the predominant chaetognath in the mesopelagic domain, inhabits most abundantly at a depth of about 200 m and is unlikely to be a diurnal vertical migrant as mentioned later.

2. Temperature and salinity distribution in the epipelagic domain

The oceanographical data such as temperature and salinity collected on the cruises of the "Oshoro Maru II and III" have been published in "*Data Record of Oceanographic Observations and Exploratory Fishing,*" Nos. 3–5 and 13 (Faculty of Fisheries, Hokkaido University, 1959–1961 and 1969). On the basis of these data the general hydrographic conditions of the area can be identified:

The temperature at the surface in the actual area ranged from 2.8 to 17.8°C. It is impossible to identify the water masses in the area by the surface temperature not only because of the non-simultaneity of the observations but also the irregularity of the seasonal change of the surface temperature every year. The temperature at a depth of 100 m is more stable than the surface one, so that a pattern of the distribution of temperature can be illustrated as shown in Fig. 2, which indicates the discontinuity of temperature between Lat. 40 and 45°N. Namely, from 45 to 40°N, the temperature of the water at a depth of 100 m rapidly ascended from 2 to 5°C in the area off the east coast of Hokkaido toward Long. 150°E, and from 4 to 9°C in the eastern area beyond Long. 150°E from 45 to 40°N. The discontinuity of the water temperature at a depth of 100 m across the North Pacific Ocean along Lat. 40–45°N shown in the present study is likely to be the Polar Front Region. According to Uda (1963), the Polar Front Region lies generally between Lat. 40 and 45°N in the mid part of the North Pacific Ocean.

It is evident that the region from the northern parts of the Bering Sea to the eastern coast of the Kurile Islands through the area off the Kamchatka Peninsula was covered by waters lower than 2°C in temperature at a depth of 100 m. This region apparently coincides with the Western Subarctic Domain previously identified by Dodimead et al. (1963). Further, the southern region off the Aleutian Islands covered by waters lower than 4°C in temperature at a depth of 100

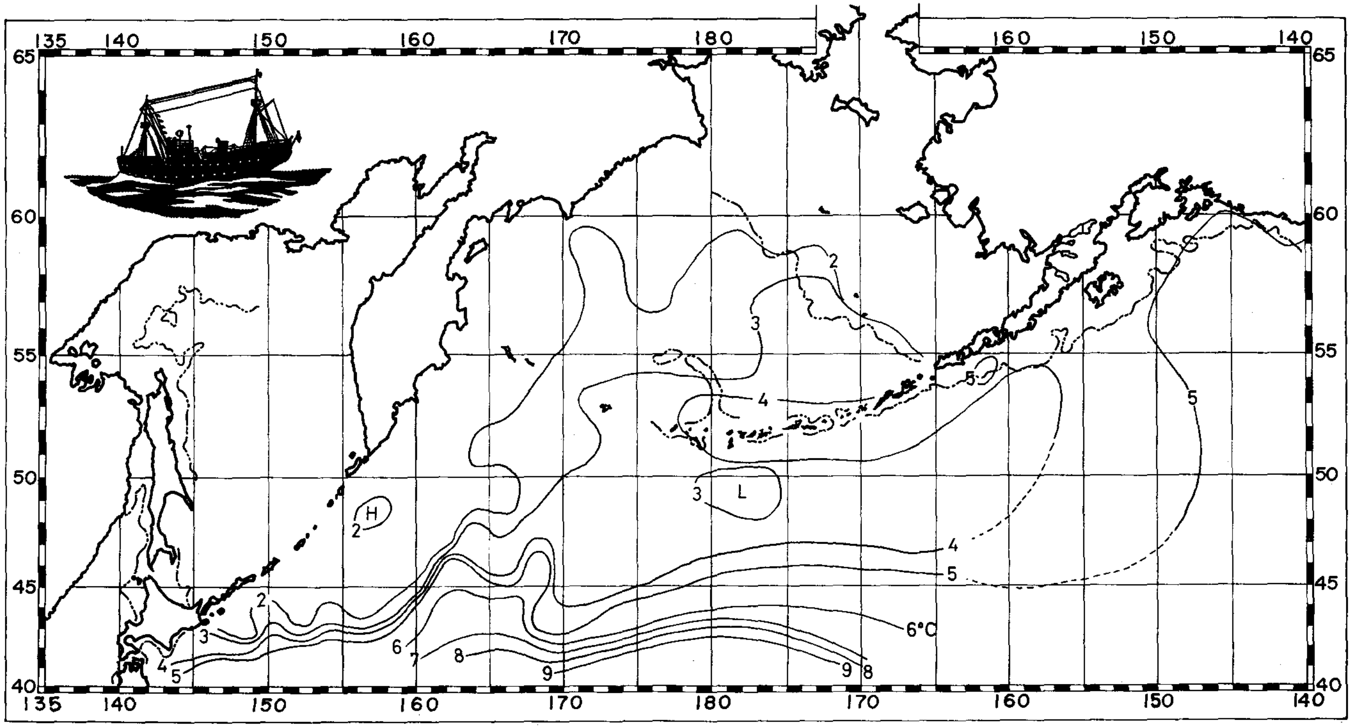

Fig. 2. Distribution of the temperature at the depth of 100 m in the Bering Sea and northern North Pacific Ocean in summer. All the data obtained in 1957, 1959, 1960 and 1968 were combined.

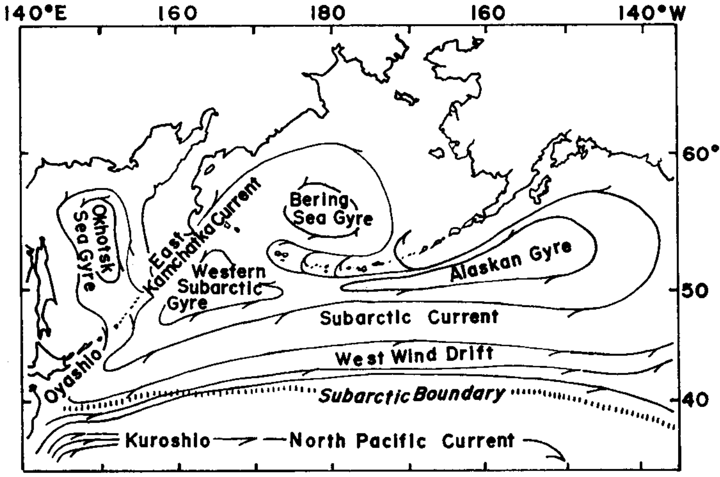

Fig. 3. Schematic representation of the surface water masses in the Bering Sea and northern North Pacific Ocean (rewritten from Dodimead et al., 1963).

m fits in the region named the Central Subarctic Domain by Dodimead et al. (1963). The schematic representation of surface water masses in the Bering Sea and the northern North Pacific Ocean presented by Dodimead et al. (1963) is shown in Fig. 3.

A pattern of the distribution of surface salinity in the present area can be illustrated, because the salinity is more stable than the temperature. Moreover, the contours of the surface salinity well agree with those at a depth of 100 m in the present area. Therefore, the present area may be divided into the following 3 regions on the basis of surface salinity: Region A covered the area over the continental shelf of the eastern parts of the Bering Sea, the Bay of Olyutorskiy, off the southern coast of Kodyak in Siberia, and the coastal area off Alaska, which were characterized by a salinity lower than 32‰ at the surface; Region B covered the Bering Sea Gyre, the Western Subarctic Gyre (Dodimead et al., 1963), the regions off the eastern coast of the Kamchatka Peninsula, the Kurile Islands and Hokkaido, on the southern coast of the Aleutian Islands, and the area from Lat. 44 to 54°N between Long. 170 and 175°E, all of which were characterized by a salinity from 32 to 33‰ at the surface; and Region C included the parts of the northern North Pacific Ocean others than Regions A and B, and being characterized by a salinity higher than 33‰ at the surface (Fig. 4).

It is suggested that Region B approximately corresponded to the Western Subarctic Domain and the Central Subarctic Domain. In the former Domain the temperature was lower than 2°C and in the latter Domain it was lower than 4°C.

3. Vertical section of temperature, salinity and dissolved oxygen content from Lat. 35°N to 50°N on the line of Long. 155°W

The vertical distribution of temperature, salinity, and dissolved oxygen

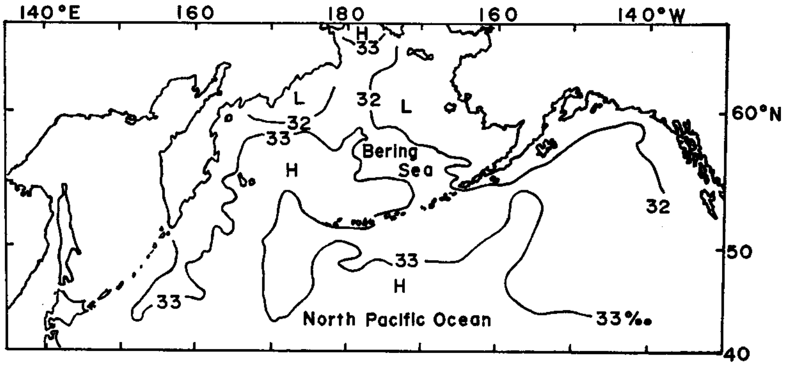

Fig. 4. Distribution of the salinity at the surface in the Bering Sea and northern North Pacific Ocean in summer. All the data obtained in 1957, 1959, 1960 and 1968 were combined.

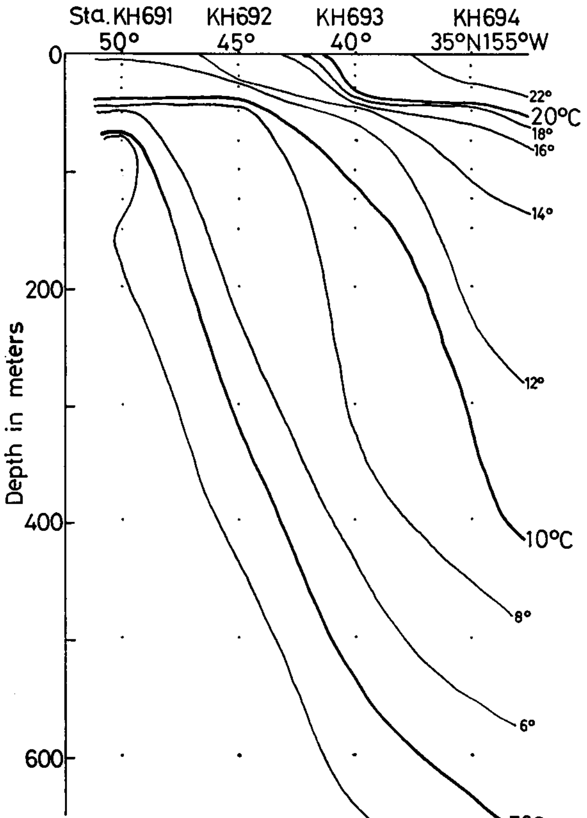

Fig. 5. Distribution of the temperature in a vertical section along long. 155°W from 50°N to 35°N during the summer of 1969.

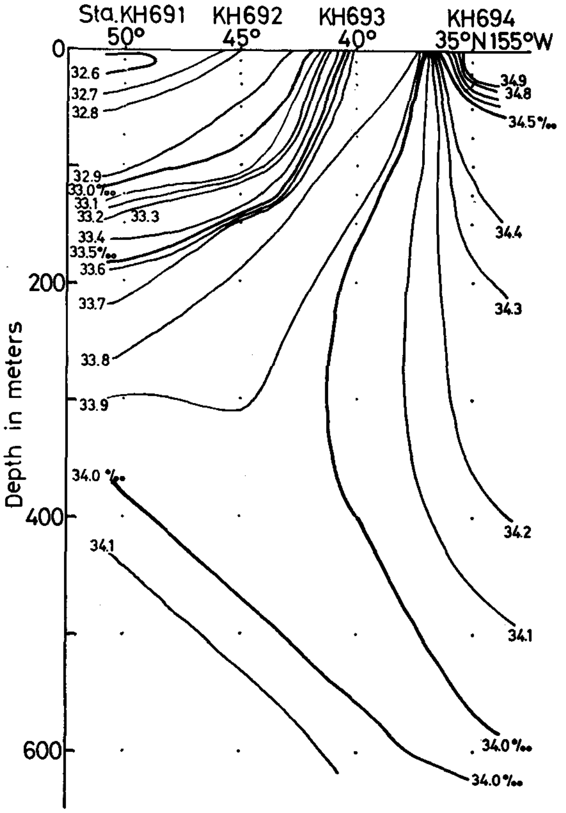

Fig. 6. Distribution of the salinity in a vertical section along long. 155°W from 50°N to 35°N during the summer of 1969.

content at 4 stations (KH691, KH692, KH693 and KH694) are shown in Figs. 5, 6, and 7, respectively. All the data given were obtained during the KH–69–4 Cruise, and have been already published in the "*Preliminary Report of the Hakuhō Maru Cruise KH-69-4*" (Marumo, 1970 ed.). The general hydrographic conditions at these stations were identified mainly on the basis of the temperature-salinity analysis by Marumo et al. (1970) in the "*Preliminary Report*" as follows: Stas. KH691 and KH692 are positioned in the Pacific Subarctic Water; Sta. KH693 in the mixture of the Pacific Subarctic Water and the Western North Pacific Central Water; and Sta. KH694 in the boundary of the Western North Pacific Central Water and the Equatorial Water. This view is supported in the present study (Fig. 8, cf. Sverdrup et al., 1942). However, the oceanographic characteristics of Stas. KH691 and KH692 in the Subarctic Water somewhat differed from one another: The thermocline was distinct in the shallow thin layer between 30 and 75 m (11.78–3.99°C) at Sta. KH691 but indistinct at Sta. KH692 where the temperature lower than 4°C appeared in the water deeper than 500 m (Fig. 5).

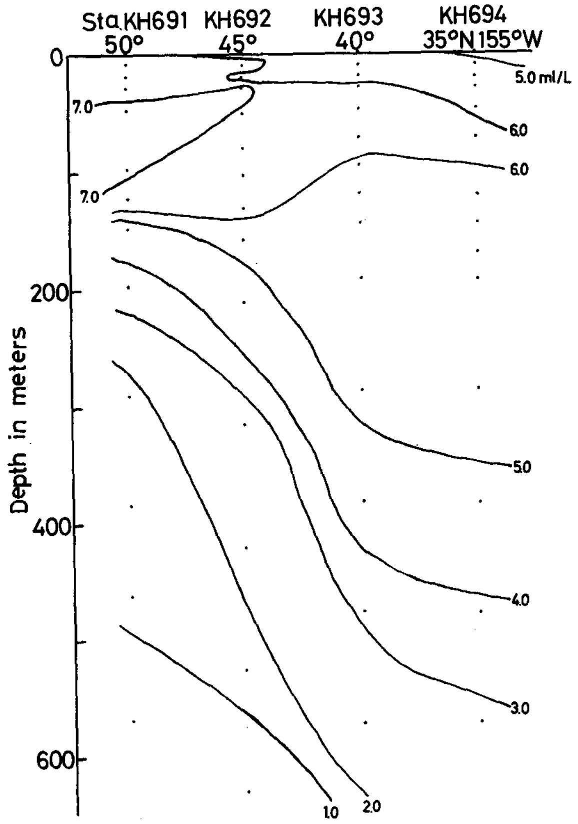

Fig. 7. Distribution of the dissolved oxygen content in a vertical section along long. 155°W from 50°N to 35°N during the summer of 1969.

Between Stas. KH692 and KH693 the surface temperature ascended rapidly from lower than 16°C to higher than 20°C, and so did the surface salinity from lower than 33.00‰ to higher than 33.50‰ (Fig. 6). These are also indicative of the existence of the Polar Front Region between Stas. KH692 and KH693. Moreover, it was noted that the high saline water of more than 34.50‰ was found in the upper 30-m depths at Sta. KH694, while the salinity was less than 34.10‰ through the whole depths at Sta. KH693.

4. Results and discussion

(1) Chaetognath species in the area

Seventeen species in 4 genera of chaetognaths were identified: *Sagitta enflata* Grassi, *S. hexaptera* d'Orbigny, **S. lyra* Krohn, **S. scrippsae* Alvariño, **S. maxima* (Conant), **S. elegans* Verrill, **S. nagae* Alvariño, *S. pacifica* Tokioka, *S. neglecta*

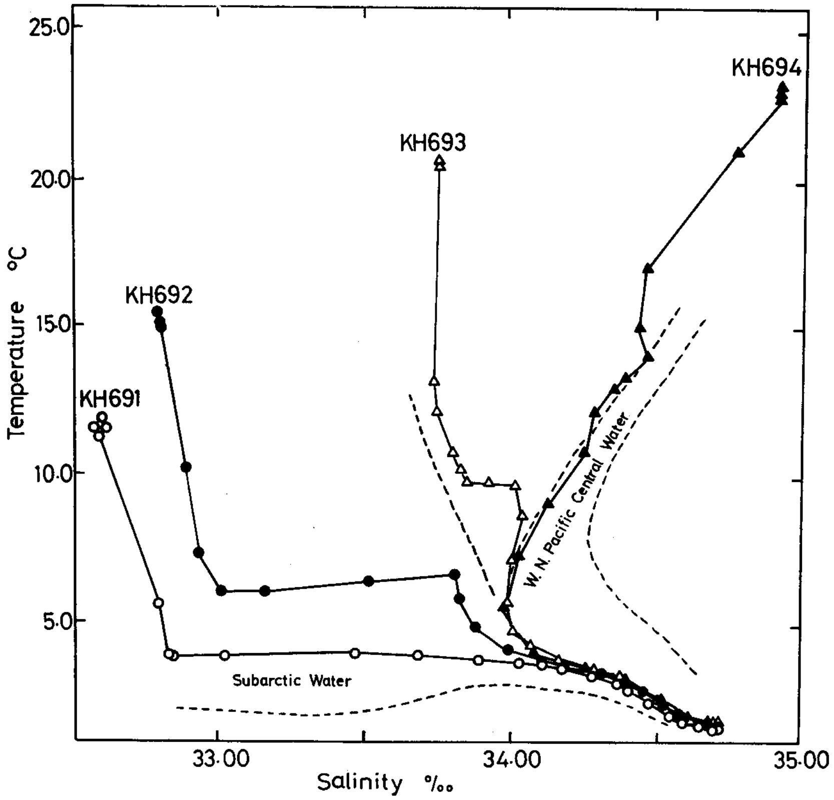

Fig. 8. Temperature-salinity curves at 4 stations where the vertical distribution of chaetognaths was examined.

Aida, **S. minima* Grassi, *S. neodecipiens* Tokioka, *S. zetesios* Fowler, *S. macrocephala* Fowler, *Pterosagitta draco* (Krohn), **Eukrohnia hamata* (Möbius), *E. bathypelagica* Alvariño and *Krohnitta subtilis* (Grassi).

Seven of these species have their habitat in the Bering Sea: *S. scrippsae*, *S. maxima*, *S. elegans*, *S. macrocephala*, *E. hamata*, *E. bathypelagica*, and *E. fowleri*. They have been listed up already (Chindonova, 1955; Alvariño, 1962; Kotori and Hara, 1972). Only three species, *S. maxima*, *S. elegans* and *E. hamata*, were collected by 0–150 m vertical hauls in the Bering Sea in the present study, while *S. scrippsae*, *S. macrocephala*, *E. bathypelagica* and *E. fowleri* were not collected by the hauls. This may confirm the previous results that *S. macrocephala*, *E. bathypelagica* and *E. fowleri* were distributed in the meso- or bathypelagic layers in the Bering Sea (Alvariño, 1962; Kotori, 1972). *S. scrippsae* was recorded only once from the depths of 335–669 m in the Bering Sea by Kotori and Hara (1972).

In the Subarctic Water of the northern North Pacific Ocean, nine species *S.*

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* The asterisked seven species were collected by 0–150 m vertical hauls with a Norpac net during the present research.

lyra, *S. scrippsae*, *S. elegans*, *S. macrocephala*, *S. zetesios*, *S. nagae*, *S. minima*, *E. hamata*, *E. bathypelagica* were collected from the depths shallower than 700 m. They are recorded in the present study. The results corresponded to those found by Chindonova (1955) in the Kurile-Kamchatka Trench, by Kitou (1967a) at 42°N 155°E in the northern North Pacific Ocean, and by Kotori (1972) in the Subarctic Water of the Pacific Ocean, although *E. fowleri* and *Heterokrohnia mirabilis* were not collected in the present study, because they are known to be bathypelagic chaetognaths living in waters deeper than 1,000 m (Chindonova, 1955; Kitou, 1967a).

(2) Areal distribution of chaetognaths

The areal distribution of 7 species collected by 0–150 m vertical hauls with a Norpac net is considered here (Figs. 9, 10, 11 and 12).

Sagitta elegans: This is the most abundant and widely distributed species in the present area: it appeared at 165 stations over a total of 168; it was also the predominant chaetognath at 139 stations in the present observation (Figs. 9 and 10). The maximum abundance (197,000 individuals/1,000 m^3) was recorded at Sta. 604640 (58°10'N 164°42'W, Appendix IA-B),* and the average number of individuals was 10,000/1,000 m^3 throughout the 168 stations in the present study. Chindonova (1955) suggested, however, that the abundance of *S. elegans* was 500–1,500 individuals/1,000 m^3 in the upper 350–m waters in the Kurile-Kamchatka Trench. The discrepancy between the results obtained by Chindonova (1955) and those in the present observation seems to be due to the facts that *S. elegans* is consentrated vertically from 70 to 200 m (Kotori, 1972), and that the present materials were collected by the upper 150–m vertical hauls, while Chindonova's (1955) materials were collected from the upper 350–m waters.

It should be noted that *S. elegans* appeared most abundantly in the eastern part of the Bering Sea: the average individual number of the species was 25,000 /1,000 m^3 through the 52 stations on the continental shelf in the eastern part of the Bering Sea, that number being more than twice the average individuals throughout

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* The present values of the standing stocks of chaetognaths obtained in the waters shallower than 150 m on the continental shelf in the eastern part of the Bering Sea must be somewhat overestimated. Motoda and Minoda (1974) and Motoda (1975) pointed out that the vertical gradient in the zooplankton biomass was sometimes so large that the standing stocks based on different-depth vertical hauls could not be compared. They also suggested that the zooplankton biomass in the upper 80 m corresponded to about 80% of the biomass in the upper 150 m in the Bering Sea. The present high values of the standing stocks obtained on the continental shelf in the eastern part of the Bering Sea are based mainly on the upper 80-m vertical hauls (Appendix IA). Therefore, it may be safe to assume that the rate of overestimation in the present study on the continental shelf would be about 20%. Accordingly, it appears that the feature of the areal distribution presented here is not so distorted by this overestimation as to be abandoned (see also pp. 102–103 in the text). Motoda and Minoda (1974) also found high values of the zooplankton biomass on the continental shelf in the southern parts of the eastern Bering Sea in summer.

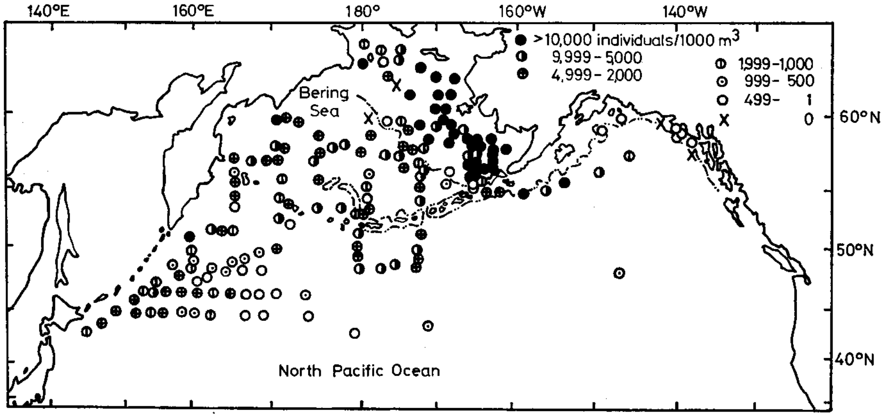

Fig. 9. Distribution of *Sagitta elegans* (individuals per 1,000 m^3) in the upper 150-m water column in the Bering Sea and northern North Pacific Ocean in summer. All the data obtained in 1957, 1959, 1960 and 1968 were combined.

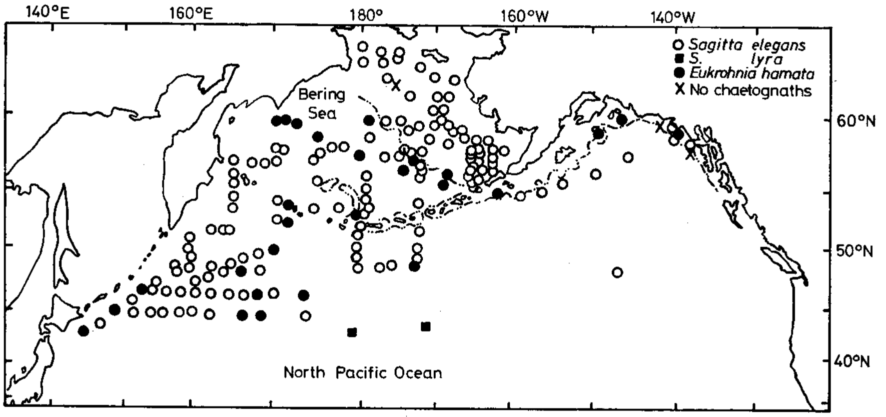

Fig. 10. Dominant species of chaetognaths in the upper 150 m in the Bering Sea and northern North Pacific Ocean in summer. All the data obtained in 1957, 1959, 1960 and 1968 were combined.

the 168 stations for the present sampling, and more than 8 times the average number of individuals (3,000/1,000 m^3) found at 116 stations situated on the other parts of the present area.* *S. elegans* was also distributed abundantly in the area off the eastern coast of Kamchatka, the Kurile Islands, and Hokkaido. However, the species was only scarcely distributed on the southern coast of Alaska, the average number of individuals through Stas. 682851–54, and 56–59 in the area being less than 100/1,000 m^3 in the present observation, although Bieri (1959) indicated that *S. elegans* was abundant in the central parts of the Gulf of Alaska. Sund (1959a) recorded that the number of individuals of *S. elegans* was 130–7,540 /1,000 m^3 in the Gulf of Alaska in August and September.

In the southern region below the latitude of 50°N, the species diminished rapidly, especially in the eastern sea from the longitude of 165°E, where the influence of the southward current of the Oyashio is not as strong as in the western parts of the North Pacific Ocean (Uda, 1963); the average number of individuals collected through the 15 stations in the area being less than 1,000/1,000 m^3 in the present observation. It has been already suggested that *S. elegans* is a typical indicator species for the Subarctic Water in the North Pacific Ocean by several authors, namely Bieri (1959), Tokioka (1959) and Furuhashi (1961). The present results described above also strongly support the view presented by the previous workers (Bieri, 1959; Tokioka, 1959; Furuhashi, 1961).

Eukrohnia hamata: It has been already recorded that *E. hamata* is distributed in the large vertical range from the surface to a depth of about 2,000 m with the maximal abundance at 120–270 m in the northern North Pacific Ocean and the Bering Sea in summer (Chindonova, 1955; Kotori, 1972; Kotori and Hara, 1972). As was already pointed out by Lea (1955), who observed some chaetognaths collected in the coastal waters of British Columbia, western Canada, *E. hamata* was next to *S. elegans* in abundance in the upper 150 m in most parts of the present area: *E. hamata* appeared at 121 stations over a total of 168 stations in the present study (Fig. 11), distributed predominantly at 27 stations (Fig. 10). The maximum abundance (14,000 individuals/1,000 m^3) was recorded at Sta. 594449 (58°18′N 169°58′E, Appendix IA-B), and the average number of individuals was 2,000/1,000 m^3 throughout a total of 168 stations for the present sampling. The present results for the abundance of *E. hamata* corresponded to those described by Sund (1959a).

It is interesting to note that *E. hamata* did not appear in the eastern part of the Bering Sea (Fig. 11), where *S. elegans* was distributed most abundantly according to the present observation. *E. hamata* was suggested to be mesoplanktonic in the Bering Sea and the northern North Pacific Ocean in the northern summer

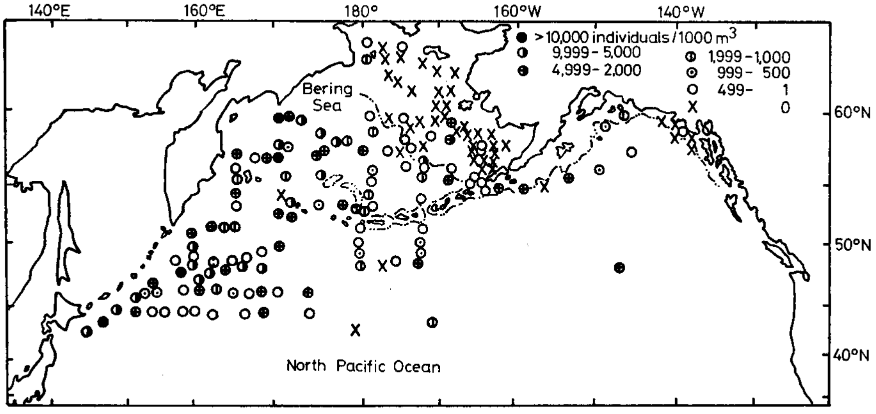

Fig. 11. Distribution of *Eukrohnia hamata* (individuals per 1,000 m^3) in the upper 150-m water column in the Bering Sea and northern North Pacific Ocean in summer. All the data obtained in 1957, 1959, 1960 an 1968 were combined.

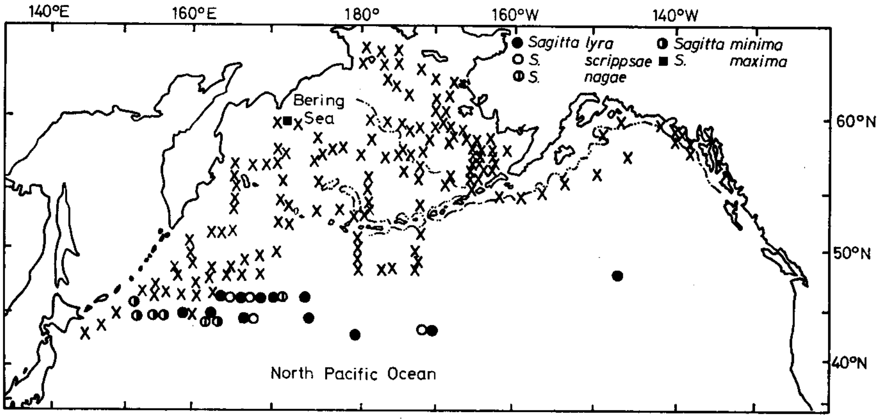

Fig. 12. Occurrence of *Sagitta lyra*, *S. scrippsae*, *S. maxima*, *S. nagae* and *S. minima* in the upper 150 m in the Bering Sea and northern North Pacific Ocean in summer. Cross indicates negative stations for these species. All the data obtained in 1957, 1959, 1960 and 1968 were combined.

(Chindonova, 1955; Alvariño, 1964; Kotori, 1969, 1972; Kotori and Hara, 1972); the present results described above may confirm the fact that the species is mesoplanktonic in the present area in summer, because *E. hamata* did not appear at the stations situated on the continental shelf shallower than 98 m in the eastern part of the Bering Sea. Moreover, it may be pointed out from the result of the present observation that *E. hamata* was somewhat more abundant off the eastern coast of the Kamchatka Peninsula and the Kurile Islands than in the other parts of the present area. However, the areal variation in abundance of *E. hamata* in the upper 150 m was not as obvious as in the case of *S. elegans* in the present observation. This may be also due to the fact that *E. hamata* inhabits more abundantly in the mesopelagic layers of the Bering Sea and the northern North Pacific Ocean during the northern summer than in the epipelagic layers.

Sagitta minima: In the present observation the species was found at only 5 stations situated west of the longitude of 165°E (Fig. 12). The maximum abundance (200 individuals/1,000 m^3) was recorded at Sta. 573924 (43°41′N 152°00′E, Appendix IA-B). *S. minima* is an inhabitant of the intermediate area between two different water masses, i.e., the Pacific Subarctic Water and the North Pacific Central Water (Bieri, 1959; Tokioka, 1959).

Sagitta lyra, S. scrippsae, and *S. maxima*: *S. lyra* was found at 12 stations widely distributed across the North Pacific Ocean along the latitude of 45°N, but was limited to the south of 50°N in the present observation (Fig. 12). The species was a predominant chaetognath at Stas. 604653 (43°09′N 170°30′W) and 604654 (42°09′N 179°42′W) for the present sampling (Fig. 10). Especially, as many as 3,000 individuals/1,000 m^3 were found at Sta. 604654.

Sagitta scrippsae was found at 4 stations from 160°E to 170°W, south of 46°N, where *S. lyra* also occurred, in the present observation (Fig. 12). *S.*

scrippsae was less in abundance than *S. lyra*, the maximum abundance of *S. scrippsae* being only 50 individuals/1,000 m^3 at Sta. 604653 (43°09′N 170°30′W, Appendix IA-B) in the present observation.

Alvariño (1962) suggested that *S. lyra* is a tropical-subtropical species, the distribution of which overlaps the southern edges of the *S. scrippsae* boundaries, which lie along the 40°N parallel in the North Pacific Ocean. The present results also indicate that *S. lyra* is a species of warm water inhabitants.

Sagitta maxima was found only at Sta. 594448 (59°19′N 172°20′E) in the northwestern part of the Bering Sea, the number of individuals of this species being 40/1,000 m^3 in the present observation (Fig. 12). Alvariño (1962) previously suggested that the species was a cold water inhabitant.

Sagitta nagae: In the present observation the species appeared only at Stas. 573908 (46°00′N 168°00′E) and 573919 (43°49′N 162°00′E), and the maximum abundance (140 individuals/1,000 m^3) of this species recorded at Sta. 573919 (Fig. 12). *S. nagae* has been suggested to be a species of inhabitants of the mixed water between the cold and the warm water in the off-shore seas (Tokioka, 1959; Alvariño, 1967b).

(3) Areal variation in the abundance of the chaetognath biomass

The areal variation in abundance of the total chaetognath biomass in the present area is illustrated in Fig. 13. Large amounts, i.e., more than 10 g wet weight/1,000 m^3 were found in the eastern part of the Bering Sea,* in the area off the eastern coast of Kamchatka, the Kurile Islands and Hokkaido, and in the southern coastal waters along the Aleutian Islands in the North Pacific Ocean. Especially in the eastern part of the Bering Sea and the coastal area on the Kurile Islands in the North Pacific Ocean, the chaetognath biomass sometimes reached

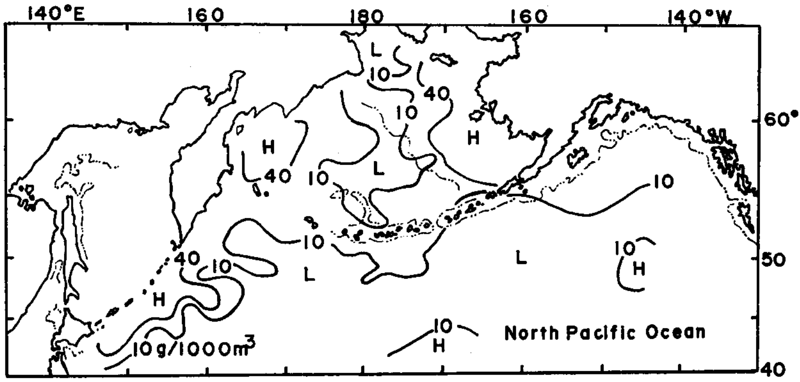

Fig. 13. Areal distribution of the total chaetognath biomass in the upper 150 m (g wet weight per 1,000 m^3) in the Bering Sea and northern North Pacific Ocean. All the data obtained in 1957, 1959, 1960 and 1968 were combined.

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* See footnote on page 110.

Table 3. *Biomass of all the chaetognaths,* Sagitta elegans *and* Eukrohnia hamata *(g wet weight per 1,000 m*^{3}*), and percentage of the chaetognaths with regard to the whole of zooplankton in the biomass in the Bering Sea and northern North Pacific Ocean in the summers of 1957, 1959, 1960 and 1968.*

Area	Bering Sea	Northern North Pacific
Number of stations	87	76
Mean biomass (Range) (g/1000 m^3)		
Total chaetognaths	31.0(0.0-183.8)	13.7(0.0- 55.6)
Sagitta elegans	27.1(0.0-151.0)	9.8(0.0- 46.5)
Eukrohnia hamata	1.9(0.0- 23.7)	3.5(0.0- 28.9)
Percentage of wet weight of chaetognaths to whole zooplankton (%)	8.1(0.4- 60.5)	9.5(0.0-100.0)

40–180 g wet wt/1,000 m^3. On the other hand, only small amounts of the total number of chaetognaths, i.e., less than 10 g wet wt/1,000 m^3 were observed mostly in the central parts of the Bering Sea and in the area south of about 50°N in the North Pacific Ocean. The average chaetognath biomass (31.0 g/1,000 m^3) through a total of 87 stations in the Bering Sea was higher than the one found (13.7 g /1,000 m^3) through 76 stations in the northern North Pacific Ocean (Table 3).

The fraction of the total chaetognath biomass in comparison with the total amount of zooplankton in wet weight was expressed as an average of 8.1% through the 87 stations in the Bering Sea, and 9.5% through the 76 stations in the northern North Pacific Ocean (Table 3). Although the present figures of 8.1–9.5% are lower than that (15%) reported by Menzel and Ryther (1961 Ms., cited from Beers, 1964) in the upper 500 m in the Sargasso Sea, they may be sufficient to support the opinion that chaetognaths play an important rôle as a primary carnivore in the food webs in the Bering Sea and in the northern North Pacific Ocean.

It is clearly indicated that *S. elegans* was the most important constituent of all chaetognaths, also in biomass, in the upper 150 m in the present area.

(4) Vertical distribution of chaetognaths

Chaetognaths can be placed in three categories according to the depths of their habitat, i.e., epiplanktonic (upper 150–200 m), mesoplanktonic (200–1,000 m), and bathyplanktonic species (below 1,000 m) (Alvariño, 1964). The vertical distribution of 13 species is considered here mainly from the materials collected at 4 stations (KH691, KH692, KH693, and KH694) by simultaneous horizontal tows with nine or ten MTD 56-cm nets.

Sagitta elegans: This species appeared abundantly in the upper 200 m at Stas. KH691 and KH692 in the Subarctic Water. In the daytime collection, the maximum abundance (5,700 individuals/1,000 m^3) was observed at a depth of 25 m at Sta. KH691, where this species also had a marked secondary concentration (3,700 individuals/1,000 m^3) at 70 m. The tendencies in the vertical distribution of this species observed at Sta. KH691 were the same at Sta. KH692: the maximum

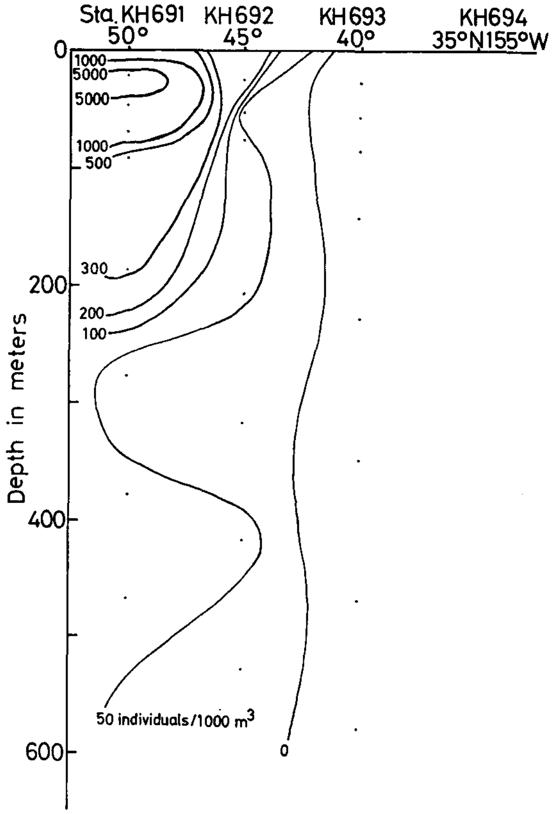

Fig. 14. Distribution of *Sagitta elegans* (individuals per 1,000 m^3) in the vertical section along long. 155°W from 50°N to 35°N in the daytime in the summer of 1969.

abundance (about 250 individuals/1,000 m^3) was in the upper 25 m, and a marked secondary concentration was from 80 to 200 m (Fig. 14). In the present observation, the shallower concentration of this species mainly consisted of small *S. elegans*, less than about 10 mm, as was pointed out earlier by the present author (Kotori, 1972). Consequently, all of these results support the opinion that *S. elegans* is an epiplanktonic chaetognath (Chindonova, 1955; Furuhashi, 1961; Alvariño, 1964; Kitou, 1967a). However, it is noteworthy that *S. elegans* may be able to live in waters deeper than 200 m, because the present results indicate this species is distributed at about 600 m at Stas. KH691 and KH692. The information that *S. elegans* reached the deep layers of 700 m in the subarctic waters has been reported by Kotori (1969, 1972) and Kotori and Hara (1972).

On the other hand, *S. elegans* was completely absent at Sta. KH693, which was identified to be in the mixture of the Pacific Subarctic Water and the Western North Pacific Central Water. Marumo (1966) previously indicated that *S. elegans* can be transported by the Oyashio undercurrent so as to be found in the intermediate water of Sagami Bay at depths exceeding 300 m in winter. Moreover, this species was suggested to be able to live at a depth of 700 m as was already described. At Sta. KH693, however, *S. elegans* did not appear even at the depths of more than 300 m. Therefore, this finding suggests that the water below 300 m at Sta. KH693 did not have the character of the Subarctic Water in view of the biological oceanography (Motoda et al., 1950; Parsons and Takahashi, 1973). *S. elegans* did not appear at the surface at Sta. KH694 situated at the boundary of the Western North Pacific Central Water and the Equatorial Water.

Eukrohnia hamata: The maximum abundance of this species was found at 190 m at Sta. KH691 (50°N), at 320 m at Sta. KH692 (45°N), and below 580 m at Sta. KH693 (40°N) (Fig. 15). *E. hamata* has been reported to occur frequently in the high-arctic part of the Norwegian Sea off northwestern Greenland and Spitsbergen, commonly in the low arctic, temperate, and tropical latitudes in the Atlantic, although in small numbers, in deeper water, and abundantly again south of the tropical zone with the maximum in the shallow water (Thiel, 1938). This holds generally for the Pacific Ocean (Alvariño, 1964).

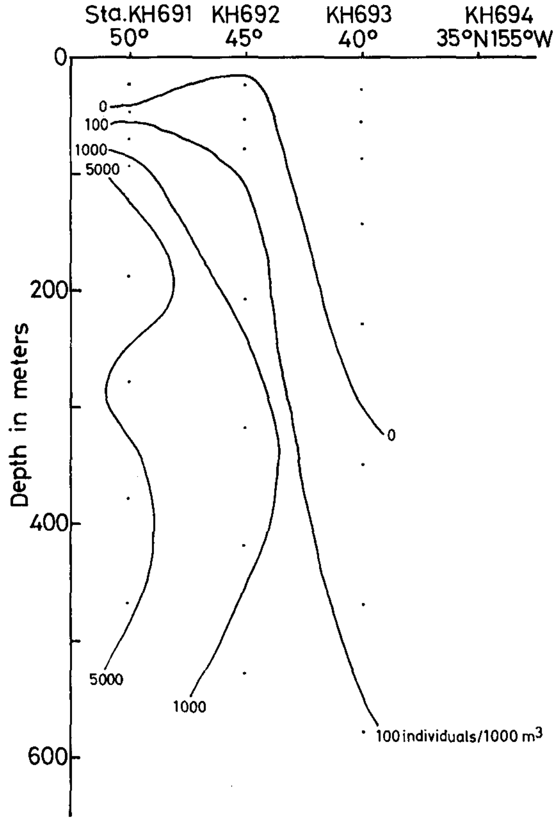

Fig. 15. Distribution of *Eukrohnia hamata* (individuals per 1,000 m^3) in the vertical section along long. 155°W from 50°N to 35°N in the daytime in the summer of 1969.

According to Alvariño (1964), the maximum abundance of the species was at a depth of 225 m at 47°35.7′N 167°44.8′E in the northern North Pacific Ocean. Kotori (1972) reported that the maximum abundance of this species was found at 120–270 m in the Bering Sea and the northern North Pacific Ocean in summer. The greatest depth of occurrence was assumed to be 1,000–2,000 m (Chindonova, 1955). Tokioka (1959) reported *E. hamata* to be rare in 0 to 50–m vertical hauls in the Oyashio water from August to September.

In the daytime collection, this species did not appear in the upper 24 m at Sta. KH691, nor at the surface at Sta. KH692, nor in the upper 230 m at Sta. KH693. However, at night, they appeared at the surface at Sta. KH691. It has been suggested that *E. hamata* did not appear at the surface either during daytime or at night in the subarctic waters in summer according to a previous work by the present author (Kotori, 1972). However, Kotori and Hara (1972) found a small number of this species at the surface of the Bering Sea at night, late in June. This may be indicative of the diel vertical migration of *E. hamata*. However, the maximum abundance of the species was at a depth of 190 m during the daytime, and at 230 m at night at Sta. KH691 for the present sampling. Therefore, the diel vertical migration of this species was probably not as conspicuous as that of *S. elegans* if *E. hamata* would migrate diurnally vertically. Kitou (1967b) noted that this species was abundant in shallow water in the western region of the northern North Pacific Ocean in May, and that conspicuous seasonal variations near the surface were related to its ontogenetic migration.

Sagitta scrippsae: This species appeared below 470 m in small numbers (20 individuals/1,000 m^3) at Sta. KH691, and below 30 m with the maximum abundance of 2,800 individuals/1,000 m^3 at a depth of 90 m at Sta. KH693 (Fig. 16). This suggests that *S. scrippsae* was much more abundant in the mixture of the Pacific Subarctic Water and the North Pacific Central Water with the vertical concentration in the epipelagic layers of this region, so as to confirm the previous information on the distribution of this species provided by Alvariño (1962, 1964) and Kotori (1972). Alvariño (1964) noted that *S. scrippsae* occurred primarily in the upper 200 m (epiplanktonic), and went deeper near the southern boundary of the California Current. Kotori (1972) suggested that the range of the vertical distribution of the species was 50–390 m in the northern North Pacific Ocean in summer.

Sagitta minima: This species was found from the surface down to 580 m only at Sta. KH693 (Fig. 17). It may be suggested that *S. minima* can inhabit not only in the epipelagic but also in the mesopelagic layers in the present area. *S. minima* appears to be epipelagic (Marumo et al., 1958; Furuhashi, 1961). However, Alvariño (1964) stated that some specimens of *S. minima* larger than the average were found from 700 to 280 m at 38°20′N 127°05′W in the North Pacific Ocean.

Eukrohnia bathypelagica: This species was found below 190 m at Sta. KH 691, somewhat increasing in number from 380 to 470 m. At Sta. KH692, it appeared only below 530 m (Fig. 17). Neither could Kitou (1966b) obtain this species in the upper 500 m south of 38°N, but he (Kitou, 1967a) found a large

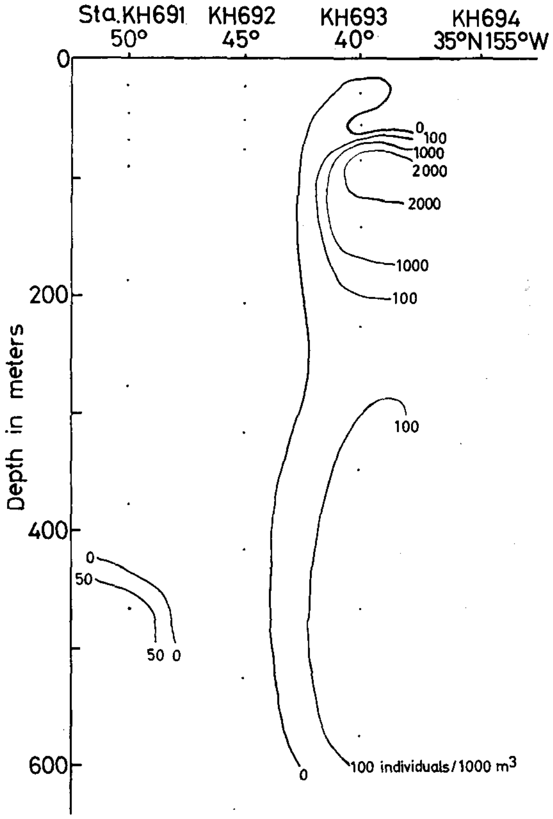

Fig. 16. Distribution of *Sagitta scrippsae* (individuals per 1,000 m^3) in the vertical section along long. 155°W from 50°N to 35°N in the daytime in the summer of 1969.

population between the surface and 700 m at 42°N 155°E, east of Hokkaido. Kotori (1972) noted that the species was distributed below 150 m in the northern North Pacific Ocean. For the present sampling, *E. bathypelagica* was completely absent at Stas. KH693 and KH694. These findings support the opinion that *E. bathypelagica* is an inhabitant of the meso- and bathypelagic layers in the northern North Pacific Ocean (Alvariño, 1962).

Sagitta macrocephala: Alvariño (1964) stated that this species extended from the lower levels of the mesopelagic domain to the upper part of the bathypelagic domain in the Pacific Ocean. Chindonova (1955) reported it below 500 m in the Kurile-Kamchatka Trench. Kitou's (1963, 1966b, 1967a) results, however, showed that the species was bathyplanktonic in the Japan Trench, because he could not collect them in the upper 1,000 m in this Trench. In the present observation, *S. macrocephala* was found below 700 m only at Sta. KH693 (Fig. 17). The author (Kotori, 1972) previously reported that the species was found in the meso- and bathypelagic layers of the Bering Sea and the northern North

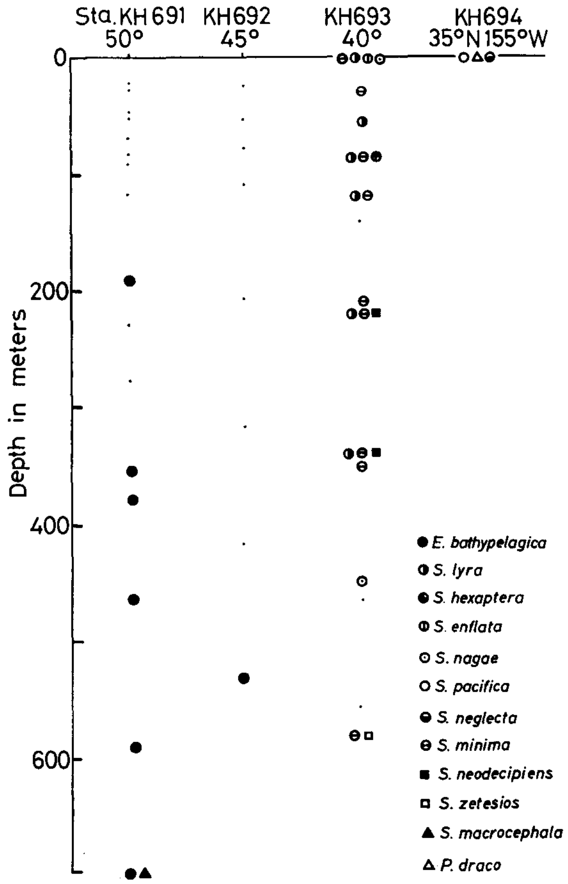

Fig. 17. Occurrence of 12 species of chaetognaths, *Sagitta enflata, S. hexaptera, S. lyra, S. nagae, S. pacifica, S. neglecta, S. minima, S. neodecipiens, S. zetesios, S. macrocephala, Pterosagitta draco* and *Eukrohnia bathypelagica* in the vertical section along long. 155°W from 50°N to 35°N in the summer of 1969. The data obtained in the daytime and at night were combined.

Pacific Ocean. All the results described above, except for Kitou's (1963, 1966b, 1967a), support the Alvariño's (1964) opinion. Kitou's (1963, 1966b, 1967a) results are probably indicative of the latitudinal variation in the vertical distribution of this species. As mentioned before, it has been established as a well-known fact for *Eukrohnia hamata* (Thiel, 1938; Alvariño, 1964).

Sagitta lyra, S. hexaptera, S. nagae, S. enflata, S. neodecipiens and *Krohnitta subtilis*: All of these six species appeared only at Sta. KH693 for the present sampling (Fig. 17).

S. lyra appeared above the 340-m depth, *S. hexaptera* was distributed from 88 to 120 m, and *S. enflata* appeared only at the surface in the present observation.

The findings confirm that these species are epiplanktonic (Alvariño, 1964; Kitou, 1966a; Fagetti, 1972).

S. nagae was found at the surface and at a depth of 450 m in the present study. In Suruga Bay, Nagasawa and Marumo (1972) reported that this species was usually distributed in the upper 100 m.

S. neodecipiens was distributed from 230 to 340 m. It confirms that the species is epi- and mesoplanktonic (Kitou, 1966a).

Krohnitta subtilis appeared in the surface and at a depth of 350 m in the present observation, and is therefore an epi- and mesoplanktonic chaetognath. The result corresponds to the Fagetti's (1972) findings.

(5) Diel vertical migration of *Sagitta elegans*

It has been suggested that *S. elegans* performs a diel vertical migration (Kotori, 1972; Pearre, 1973). However, the present author suggested in his previous paper that the small *S. elegans*, less than 9 mm, did not migrate diurnally vertically (Kotori, 1972). He also suggested that a thermocline at 10–50 m impeded the upward nocturnal migration of *S. elegans* which are longer than 20 mm.

At Sta. KH691, a marked secondary concentration of *S. elegans* was observed at 70 m during daytime, and this concentration could be observed at the same depth also at night (Fig. 18A). Meanwhile, the lower part of the thermocline at this station was situated at about 70 m (Fig. 18B). Therefore, the result supports the opinion that a thermocline impedes the upward migration of *S. elegans* inhabiting in the lower parts of the thermocline (Kotori, 1972). On the other hand, the present result indicates that *S. elegans* appeared most abundantly at the surface at night, and that the maximum abundance was at 25 m during daytime. This may confirm the diurnal vertical migration of the species. Fig. 18B also shows the upper part of a thermocline situated at a depth of 30 m.

Many of the individuals of this species occurring at the surface during daytime were small *S. elegans*, as it was previously pointed out by Kotori (1972).

(6) Vertical variation in the abundance of the total population of chaetognaths

The vertical distribution of the total chaetognath biomass in the Subarctic Water can be summarized as follows:

According to Chindonova (1955), the maximum abundance is at around 150 m in the Kurile-Kamchatka Trench. Kotori (1972) mentioned that the maximum abundance in the Subarctic Water during daytime was at a depth of 100 to 300 m in spring and summer.

In the present observation, the maximum abundance was at a depth of 100 to 300 m, where *Eukrohnia hamata* was a predominant chaetognath. A marked secondary concentration was also found at a depth of 25 to 100 m, where *Sagitta elegans* predominantly appeared in the present study (Fig. 19). It confirms the view previously presented by Chindonova (1955) and Kotori (1972).

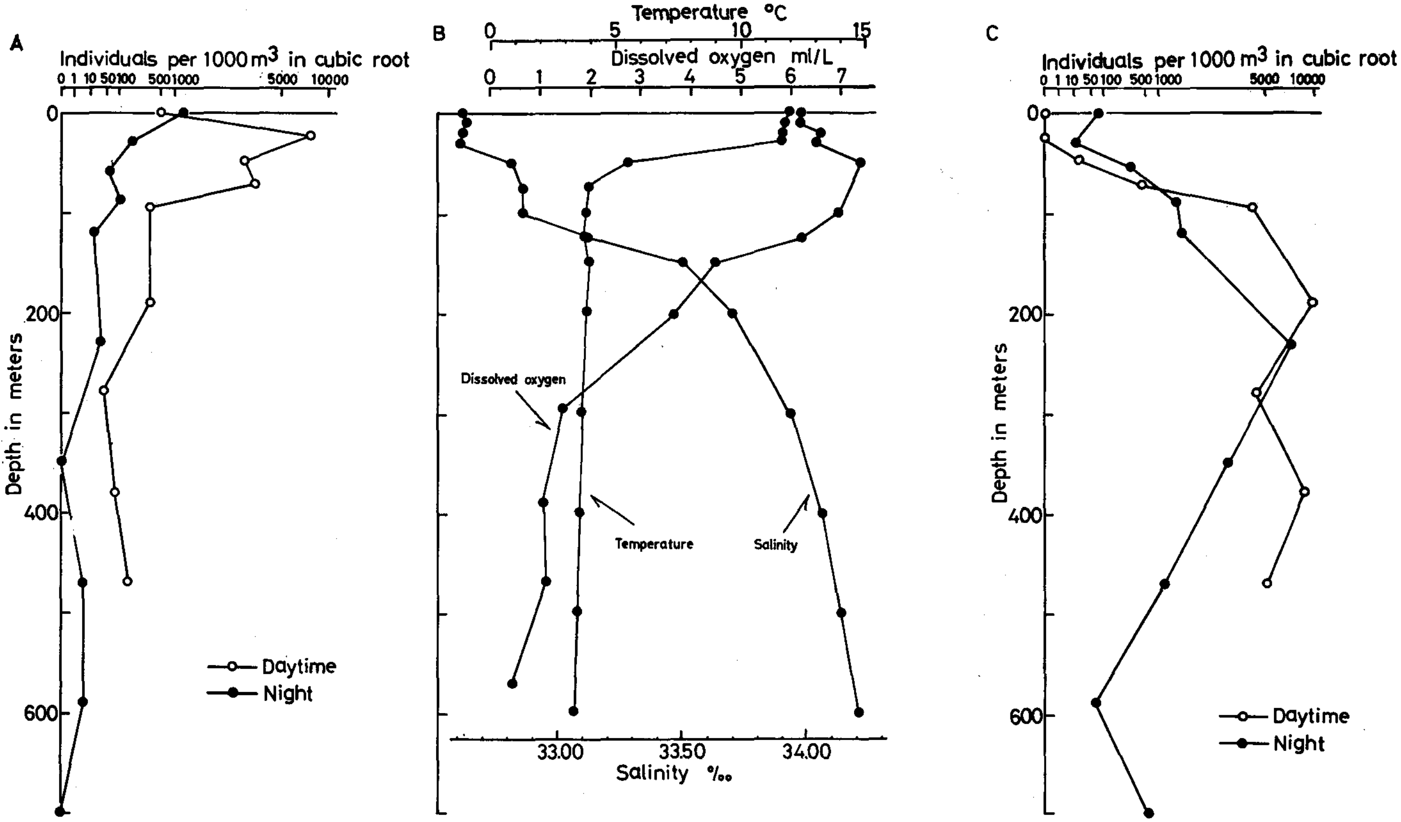

Fig. 18A-C. Vertical distribution of *Sagitta elegans* (A) and *Eukrohnia hamata* (C) (individuals per 1,000 m^3) in the daytime and at night, and vertical profiles of the temperature, salinity, and dissolved oxygen (B) at Sta. KH691 (50°N 155°W) in the northern North Pacific Ocean in August 1969.

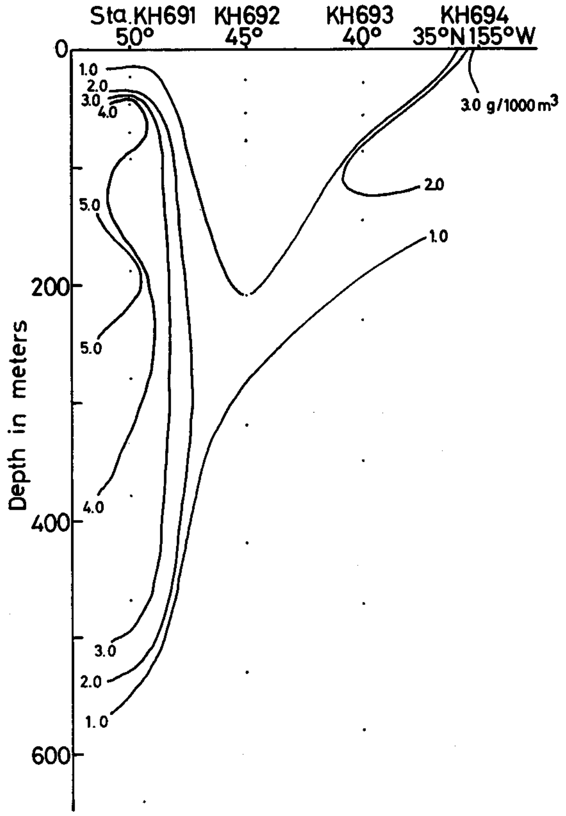

Fig. 19. Distribution of the total chaetognath biomass (g wet weight per 1,000 m³) in the vertical section along long. 155°W from 50°N to 35°N during daytime in the summer of 1969.

(7) Possible factors controlling the distribution of chaetognath species

As factors directly affecting areal and vertical distribution of chaetognaths, such phenomena as submarine light intensity, temperature, salinity, hydrostatic pressure, number of prey, concentration of dissolved oxygen, and the interaction of two or more factors should be considered. The behavioral response differs with the species, and with their developmental stage. Immature *S. elegans* are less sensitive to light than the adults, which are distributed deeper than younger animals (Russell, 1933b; Kotori, 1972). Similar differences have been reported for *Eukrohnia hamata* (Fowler, 1905; Alvariño, 1964; Kitou, 1967b), *Sagitta gazellae* (David, 1955), *S. marri* (Devid, 1958), *S. lyra* (Kitou, 1966b) and others.

In the present observation the areal and vertical distribution of temperature, salinity and dissolved oxygen were examined as parameters possibly related to the distribution of *Sagitta elegans* and *Eukrohnia hamata*.

Temperature and salinity: It was obviously illustrated that *Sagitta elegans* appeared most abundantly, while few individuals of *Eukrohnia hamata* appeared (Fig. 11), in the eastern part of the Bering Sea, which is characterized by a salinity lower than 32‰ at the surface in the present observation (Figs. 6, 9 and 11). The area is over the continental shelf of the eastern parts of the Bering Sea. Next to the area described above, many *S. elegans* were distributed in the regions off the eastern coast of the Kamchatka Peninsula, the Kurile Islands and Hokkaido, and the coastal area south of the Aleutian Islands, where the salinity was from 32 to 33‰ at the surface. On the other hand, only a few *S. elegans* were distributed in the region south of 50°N, west of 165°E, which was characterized by a salinity higher than 33‰ at the surface.

These facts described above suggest that the salinity was one of the possible factors controlling the distribution of *Sagitta elegans*.

In Fig. 20, the density of *Sagitta elegans* (individuals per 1,000 m^3) in the upper 150 m was plotted against the temperature and the salinity at the surface at each sampling station. The surface temperature at the present stations where *S. elegans* appeared ranged from 2.8 to 17.8°C. An occurrence of *S. elegans* exceeding 10,000 individuals/1,000 m^3 could be observed more frequently in the areas of lower surface salinity (less than 32.20‰) than in the areas where it was higher (more than 32.20‰). These trends, in which a few exceptions were included, may also indicate that *S. elegans* prefers areas of low salinity. This view was supported by Shimura (1975 Ms.). However, Sund (1959a) maintained that *S. elegans* was most abundant in the areas of high salinity (32.8‰) and moderately warm temperature (12–13°C) in the Gulf of Alaska. Chindonova (1955) reported that the individuals of *S. elegans* increased in number with the salinity in the Kurile-Kamchatka Trench.

On the other hand, Bieri (1959) noticed that *Sagitta elegans* appeared to be most abundant near the shore. Lea (1955) also maintained that *S. elegans* decreased in abundance as she went seaward. These phenomena may suggest that *S. elegans* prefer coastal waters of low salinity to offshore waters of high salinity. Moreover, the comparison between the vertical distribution of salinity and *S. elegans* as it is carried out in the present study may also confirm the salinity preference of *S. elegans*: This species did not appear south of Sta. KH693, which was characterized by a high salinity (more than 33.5‰); and the occurrence of more than 400 individuals/1,000 m^3 of *S. elegans* was restricted to the upper 100 m at Sta. KH691, which was characterized by low salinity (less than 33‰). These results obtained previously and confirmed in the present study all suggest that *S. elegans* prefers a low salinity of around 32‰.

In the case of the vertical distribution of *Eukrohnia hamata*, the upper limits of appearance of this mesoplanktonic species (Fig. 15) corresponded to the 8°C contour of the temperature profile (Fig. 5). Moreover, the occurrence of more than 1,000 individuals/1,000 m^3 of this species was limited to the waters of low temperature (less than 5°C) in the present study. Therefore, the temperature probably affects the distribution of this species, as Thiel (1938) previously demonstrated.

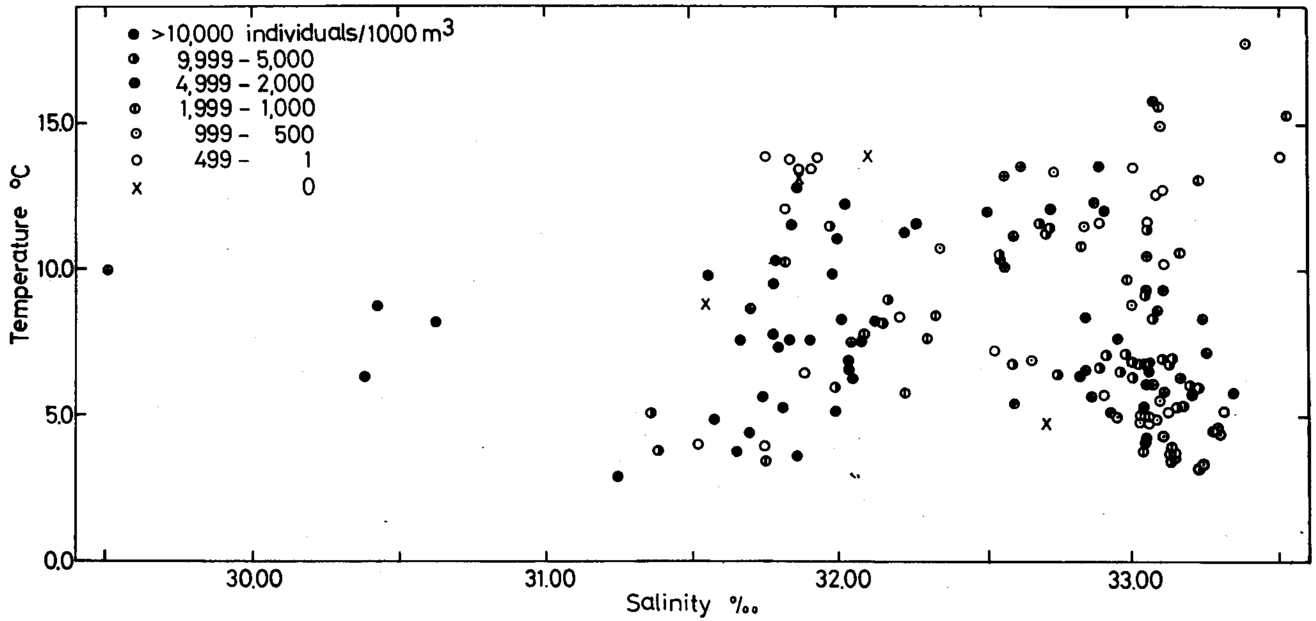

Fig. 20. Density of *Sagitta elegans* (individuals per 1,000 m^3) in the upper 150 m plotted against the temperature and the salinity at the surface at sampling stations during summer. All the data obtained in 1957, 1959, 1960 and 1968 were combined.

Dissolved oxygen: According to Alvariño (1964), the distribution of *Sagitta elegans* is limited by a concentration of oxygen below 6 ml/l in the northern North Pacific Ocean. However, Marumo (1966) collected many individuals of this species below 300 m in Sagami Bay, where the oxygen content was less than 4 ml/l. Further, Kotori (1972) found some specimens of *S. elegans* in depths containing dissolved oxygen as low as 1 ml/l in the northern North Pacific Ocean.

In the present observation, the surface water at Stas. KH691, KH692, KH693 and KH694 contained dissolved oxygen of more than 6 ml/l, but *Sagitta elegans* was distributed only at Sta. KH691 and KH692. Moreover, this species was distributed in layers deeper than 150 m where dissolved oxygen was less than 6 ml/l at Stas. KH691 and KH692 for the present sampling (Figs. 7 and 14).

In order to determine the endurance in waters of low oxygen content, a preliminary experiment was conducted in the land laboratory in the present study. Experimental animals were obtained about 1 km off the Usujiri shore, Minamikayabe, southern Hokkaido facing the northern North Pacific Ocean, about 1 hr after sunset from May 28–31, 1971. The low oxygen content water was prepared as follows: The seawater had been filtered with a Whatman glass filter (GF/C), and then it was refiltered with a HA Milipore filter (0.45 μ pore), so as to keep the oxygen contents as low as 2.03–2.54 ml/l. Details of the net used in the sampling of the experimental animals and the rearing technique employed will be presented later in the next Chapter (see pp. 127–129).

Table 4 shows the survival percentage of *Sagitta elegans* in the seawaters containing from 5.82 to 6.62 ml O_2/l, and in the low oxygen content water of 2.03 to 4.36 ml O_2/l. *S. elegans* was able to survive for at least 24 hrs under the conditions of dissolved oxygen contents as low as 2.21 and 2.54 ml/l under a low

Table 4. *Survival rates of* Sagitta elegans *under various experimental conditions.*

Exp. No.	Experimental conditions					Survival percentage during the maintenance (%)
	Number of animals experimented	Time after capture (days)	Duration of maintenance (hours)	Temperature (°C)	Initial O_2 concentration of water (ml/liter)	
1	5	2	24	8.6-11.0	5.93	100
2	5	4	24	9.2-11.0	6.62	100
3	5	10	48	8.1-12.2	6.06	100
4	5	13	24	11.8-14.8	5.92	100
5	5	16	24	2.0- 4.0	6.39	100
6	5	19	48	3.5- 4.0	5.82	100
7	6	14	48	2.0- 3.0	6.18	83
8	5	21	24	3.5	2.54	100
9	5	16	24	4.0	2.21	100
10	4	19	29	14.1-15.4	2.03	0
11	5	4	24	3.0	2.52	100
12	5	5	24	3.0	3.61	100
13	6	6	24	13.0	4.36	100

temperature of 3.5–4.0°C. However, at a high temperature of 14.1–18.4°C, animals could not be kept alive for more than 29 hrs in the low oxygen content water of 2.03 ml/1. On the other hand, they were alive for about 2 weeks in the waters containing 5.93–6.62 ml O_2/1 at 8.1–14.8°C.

It is therefore probable that the low oxygen contents do not affect the distribution of *Sagitta elegans* as much as the increase in temperature. The low oxygen content is probably non-effective at a temperature as low as 4°C, but becomes effective at about 15°C.

IV. On the biology of *Sagitta elegans* Verrill

The preceding chapters in the present study emphasized that the fraction of chaetognaths was about 10% of the total zooplankton weight in the Bering Sea and the northern North Pacific Ocean, and that *Sagitta elegans* was the most important constituent in the epiplanktonic chaetognath community in these regions. Meanwhile, there is very little information on the development, life history, metabolisms, and other ecological problems in the biology of *S. elegans* in the present regions.

This Chapter, therefore, deals with such aspects of the biology of this species as development, life history, and respiration mostly by means of the rearing of this species in the laboratory. Successful experimental works in the laboratory on neritic chaetognaths in the temperate and tropical regions have been carried out by several authors in the recent years. The maintenance of very fragile and delicate planktonic animals such as *Sagitta crassa* has been accomplished successfully by Murakami (1959, 1966) and Takano (1971), and *S. hispida* by Beers (1964), Reeve (1964, 1966, 1970a, b), Cosper and Reeve (1975), Reeve et al. (1975), and Reeve and Cosper (in press). The maintenance of *S. elegans*, an oceanic and subarctic species, was reported by Ikeda (1970), Sameoto (1972), and Kotori (1975a, b).

In the present studies, live specimens of *Sagitta elegans* were collected off Usujiri in southern Hokkaido, where it faces the northern North Pacific Ocean, in late May 1971, and in Oshoro Bay in western Hokkaido, where it faces the northern part of the Japan Sea, from February to March 1972. They were kept alive successfully for more than two weeks under starving conditions in the laboratory.

1. Materials and methods

Animals: Zooplankton samples were obtained about 1 km off Usujiri shore, Minami-kayabe, in southern Hokkaido where it faces the northern North Pacific Ocean in May, 1971, and in or off Oshoro Bay, on the west coast of Hokkaido where it faces the northern part of the Japan Sea in February and March, 1972. The sampling of the material was made with an Ikeda net (Ikeda, 1971, 1974; 0.35–mm mesh aperture, 56 cm in diameter, 100 cm in length, with a specially designed large polyethylene tail bucket, 15 cm in diameter, 25 cm in length), which was towed through the surface layer from 0 to 20 m approximately, for about 10 minutes about 1 hour after sunset. The chaetognaths collected with this net were almost vigorous and healthy in the present observation.

Experimental seawater: The seawater dipped from the surface of the sea where materials were collected was filtered through Whatman glass fiber filters (GF/C) and stored in polyethylene tanks for less than one week. Before it was used, the filtered water was aerated by means of an air compressor. No antibiotics were added to the water. This is the water which was used as the experimental seawater for the maintenance of the animals.

Rearing procedure of Sagitta elegans: The zooplankton collected with an Ikeda net was diluted in large polyethylene buckets filled with raw seawater on the boat, transported to the land laboratory (Usujiri Fisheries Laboratory or Oshoro Marine Biological Station, Hokkaido University) and then individuals of *Sagitta elegans* were carefully sorted from the composite samples with a large bore pipette (0.8 mm in diameter) in 5-liter glass containers filled with experimental seawater. The time required from the sampling to the completion of sorting was not longer than 1.5 hour. The five-liter glass containers with sorted animals were dipped in a water bath for about one day. The temperature of the water bath was kept close to natural temperature for animals by pumping seawater into the land laboratory. Then, the sorted animals in the 5-liter containers were transferred into 1-liter glass bottles filled up with the experimental seawater, and they were stocked up for the following experiments under the conditions of starvation and darkness. The bottles were placed in a refrigerator kept at about 4°C during the period of the maintenance.

The rearing was continued for 45 days until the last animal died. About one-third of the experimental seawater in the bottles was renewed every two or three days. At the same time, dead individuals, if present, were removed from the bottles. Quite recently, Reeve et al. (1975) demonstrated photographically the formation of membranes which surround the faecal materials produced by *Sagitta hispida*. However, the present author could not confirm whether *S. elegans* excreted faecal pellets or not during the experiment.

Development of Sagitta elegans: Nineteen individuals of all the *Sagitta elegans*, which were collected off Usujiri on May 30, 1971, were kept together in a 5-liter glass container set in a refregerator, under the conditions of starvation and darkness. The glass container was filled with the experimental seawater. The oxygen of the experimental seawater was 5.82–6.62 ml/1 in the present study.

Some of the reared animals spawned eggs in the glass container at 20:00 hrs on June 4, 1971. The eggs were transferred to a 1-liter glass bottle that was filled with the experimental seawater and kept under the same conditions as the 19 reared animals. After 3 days (15:30 hrs, June 7), larvae were hatched out from the eggs and found swimming in the bottle (Kotori, 1975a).

At times during the rearing of these leavae, some of them were fixed and preserved in a 3% formalin-seawater solution for later morphological observations. The larvae survived for 11 days at most. In all, 25 larvae were obtained in the laboratory (Kotori, 1975b).

To determine the later developmental processes of *Sagitta elegans*, all 83 individuals of this species ranging from about 2 to 27 mm in length were sorted from the zooplankton materials collected at Stas. 682834, 682837, 682861, 682862 and 682868 for the present study in the eastern Bering Sea, and they were observed morphologically.

Respiration: The water bottle method described by Marshall et al. (1935), Conover (1956) and Ikeda (1970, 1971, 1974) was adopted to measure respiration.

From the stocked animals in the 1-liter glass bottles, about 5 individuals (4–6 individuals) were transferred into a 1-liter well stopped glass bottle filled with the conditioning experimental seawater. Then, a rubber stopper with an outlet tube and an inlet tube, the former covered with a fine mesh net to prevent the escape of animals, the latter being connected to a large reservoir of the conditioning experimental seawater, was fitted firmly at the mouth of the bottle. The conditioning experimental seawater was flowed gently through the bottle containing animals, about 2–3 times the volume of the bottle, to replace its content with the conditioning experimental seawater. At the same time another bottle without animals was prepared the same way, to serve as control. Each bottle was covered with a black vinyl bag as soon as the replacement of the conditioning experimental seawater had been completed and immersed into the water bath. The time required for the preparation of one series of two bottles was about an hour. The time of incubation varied with the water temperature, from 24 to 51 hours, but mostly 24 hours.

At the end of the incubation, the conditioning experimetnal seawater in each bottle was siphoned to a 300-ml BOD bottle for the determination of dissolved oxygen. When dead animals were observed at the end of the incubation period, the results were not taken into account. The animals remaining with a small volume of the experimental seawater were picked up with a pipette on blotting paper and the excess of sea water adhering to the animal's body was removed. The body length of the animals was measured, and the body was transferred into an air-tight plastic pot, the bottom being covered with a glass fiber filter. The pots were kept in a desiccator (desiccant: silica gel) in a deep freezer for later measurement of weight.

The dissolved oxygen was analyzed following the Winkler method described by Strickland and Parsons (1968). The rates of respiration were calculated by the difference of the concentration between the experimental and the control bottles.

Determination of the conversion factor from wet weight to amount of carbon in mixed zooplankton: The materials were collected with a Shark high-speed plankton sampler (Motoda, 1967: 15 cm in mouth diameter, 0.35-mm mesh aperture) at the surface in the northern North Pacific Ocean during the KH-69-4 cruise of the "Hakuhō Maru," from August 16 to 29, 1969. The materials collected were weighed on board and then washed briefly with distilled water. The materials were placed on a glass filter and dried in an oven for 24 hours at 40°C, and then stored in a deep freezer at −20°C. In the land laboratory, the preserved samples were desiccated at the room temperature until a constant weight was attained. The total amount of carbon was determined with the Hitachi 026 CHN analyzer for an aliquot of ground material for a single determination.

2. Results and discussion

(1) Developmental processes of *Sagitta elegans* through its life span

As far as the individuals of *Sagitta elegans* longer than 7 mm are concerned, there have been many contributions as to its morphology (e.g. Huntsman, 1919; Russell, 1932a; Tokioka, 1940a; Lea, 1955; Dunbar, 1962; Park, 1970). Meanwhile, Huntsman and Reid (1921), Zo (1973), and quite recently Kotori (1975a, b) presented some information on the morphology of such small individuals as about 1.5 mm in length.

Information on the morphological characteristics of *Sagitta elegans* through its life span is very important to understand the life history and population dynamics of this chaetognath. In the present study, information on the developmental processes of this species through its life span are given on the basis of the results given by the present author in his previous work for the larval stages (Kotori, 1975b) and by the present observations on the materials collected in the eastern part of the Bering Sea for the elder forms of *S. elegans* (Appendix III).

As mentioned above, the morphological remarks on the larvae of *Sagitta elegans* in the early stages of development have been published elsewhere (Kotori, 1975b). They are summarized here as follows: The eggs immediately after spawning are spherical, about 0.3 mm in diameter, and most are in such an advanced state that an embryo in the eggs can be easily seen through the membrane (Plate IA). The embryo is found enclosed within the egg, with the tail overlapping the head (Fig. 21). The results of this observation on both the egg and the embryo correspond to those reported by Huntsman and Reid (1921) and Zo (1973).

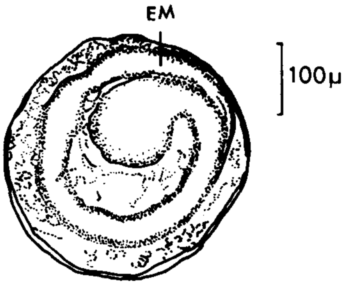

Fig. 21. Egg of *Sagitta elegans* spawned under artificial conditions in laboratory (EM; embryo).

The body length (from the tip of the head to the base of the tail) of larvae, from time of hatching to 2-days old, ranged from 1.23 to 1.42 mm long for 6 individuals. The larva is provided with a pair of posterior fins, but not yet furnished with the anterior fin; the existence of eye pigments (Huntsman and Reid, 1921) cannot be confirmed because of the thick collarette extending nearly all over the body; no hooks are developed yet; the median vertical septum is found already in the posterior portion of the body, though the tail septum is not yet formed (Fig. 22 and Plate IB-D).

Through the rearing of larvae for 12 days, it was found that most of the seven-day old larvae, 1.47–1.65 mm in length, were provided with the tail

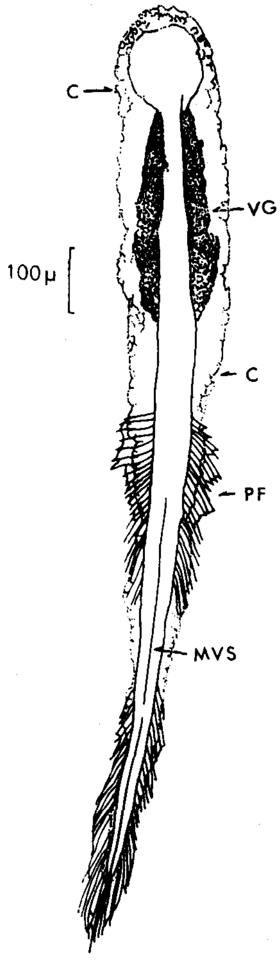

Fig. 22. Newly-hatched larva of *Sagitta elegans* (Larval Stage I), dorsal view (C; collarette. VG; ventral ganglion. PF; posterior fin. MVS; median vertical septum).

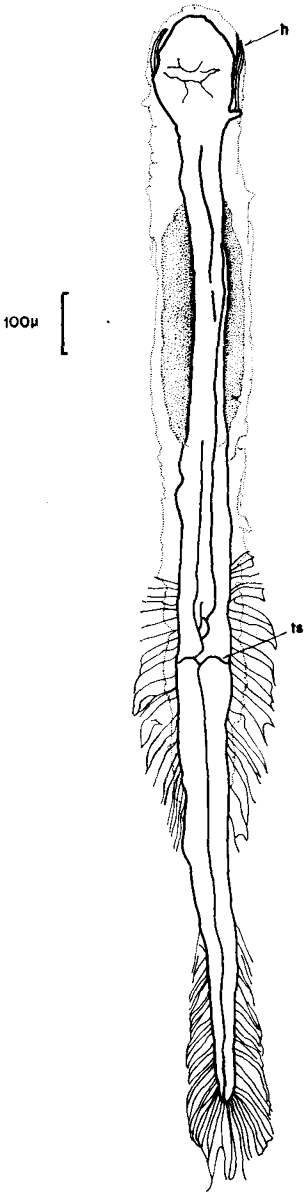

Fig. 23. Eight-day old larva of *Sagitta elegans* (Larval Stage III), dorsal view (h; hook. ts; tail septum).

septum (Plate IF), but had neither hooks nor eyes, while eight to eleven-day old larvae, 1.69–2.20 mm in length, were furnished with eight hooks on each side (Figs. 23, 24 and Plate IE), but had no eyes on the dorsal surface of the head.

These features indicate that the early morphological development of *Sagitta elegans* is similar to that of *S. crassa* observed by Murakami (1959), but somewhat different from those of *S. enflata* observed by Doncaster (1902), *S. hispida* by Reeve and Cosper (in press), and *Spadella cephaloptera* by John (1933).

On the basis of the observations on the plankton materials collected in the eastern part of the Bering Sea, the developmental processes of the elder forms of *Sagitta elegans* will be summarized as follows:

Fig. 24. Eight-day old larva of *Sagitta elegans* (Larval Stage III), ventral view of the head (h; hook).

The tail percentage (percentage of the tail length to the body length) of 19 individuals from 2.05 to 4.94 mm in length decreased from 45.4 to 24.2% with the increase in body length, while the percentage was 37.7–45.6% in 13 individuals of 7-day old larvae and 40.2–44.3% in 5 individuals of 8- to 11-day old larvae (Kotori, 1975b). This suggests that the trunk of the body of *S. elegans* developed rapidly during the period of this stage, so that the tail percentage approached closer those of the older animals. This is also confirmed in *S. hispida* by Reeve and Cosper (in press). *S. elegans* from 2.05 to 4.94 mm in length had seven or eight hooks on each side, but they did not have a pair of anterior fins in the present study. The eye pigments could be observed first in these specimens (Fig. 25).

The smallest *Sagitta elegans* having the anterior fins (No. F25 Animal in Appendix III) was 5.10 mm in length in the present study. However, even specimens longer than this, 5.20 mm (1 individual), 5.50 mm (1 individual), 6.05 mm (2 individuals) and 6.45 mm (1 individual) in length, lacked a pair of anterior fins. Therefore, it is probable that *S. elegans* obtains its anterior fins during the period of development when it is 5 or 6 mm in length.

The body length of the specimens furnished with a pair of anterior fins and having no sexual products in the body according to the microscopical observa-

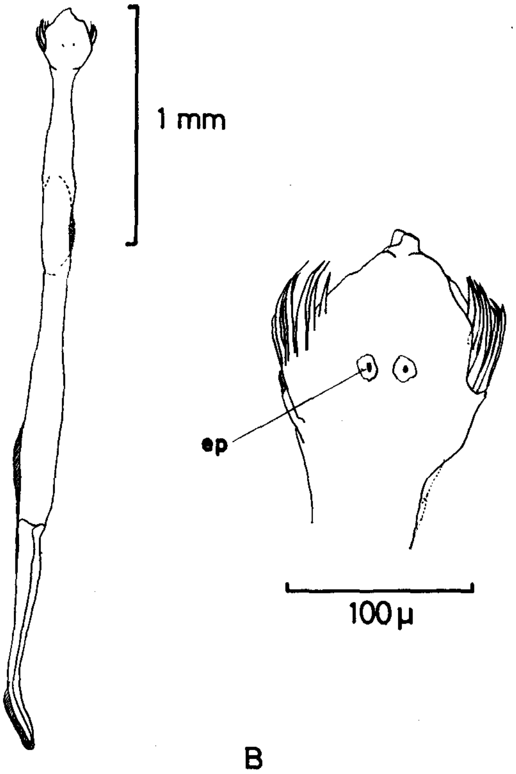

Fig. 25A-B. *Sagitta elegans*, Juvenile Stage I (3.41 mm long specimen). A: Dorsal view of the body. B: Dorsal view of the head (ep; eye pigment).

tions, varied from 5.10 to 7.91 mm for all of the 26 individuals in the present study (Fig. 26). Their tail percentage was 18.3–25.1%.

The ovarian products were first recognized in a specimen of 7.91 mm in length (No. F44 Animal in Appendix III) in the present study (Fig. 27). The seminal vesicles, however, did not develop until *S. elegans* reached 18.20 mm in length. The tail percentage of the specimens from 7.91 to 18.15 mm in length was 15.8–21.2% for 23 individuals in the present study. This approached the figures: 16.9–18.1% in the eldest specimens being 18.20–27.66 mm long for all of the 14 individuals collected in the present observation.

The smallest one of the specimens that had their seminal vesicles was 18.20 mm in length (Fig. 28A1–2, No. F71 Animal in Appendix III) in the present study. The seminal vesicles became fully developed in a specimen of 23.09 mm in length (No. F78 Animal in Appendix III), which is a maximum size for a 0.15-mm thickness. On the other hand, the ovaries developed more and more after that, increasing their length in the trunk of the body (Fig. 28B–C). It is interesting to note that the hooks of the head increased from 7 or 8 to 11 or 12 in number on each side when the seminal vesicles were built up: *S. elegans* longer than 22.95 mm in

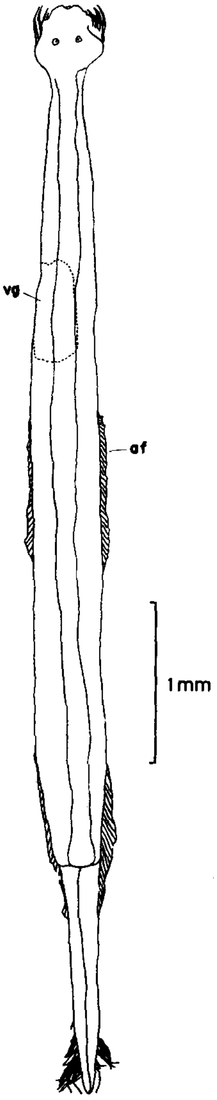

Fig. 26. *Sagitta elegans,* Juvenile Stage II (6.95 mm long specimen), dorsal view (vg; ventral ganglion. af; anterior fin).

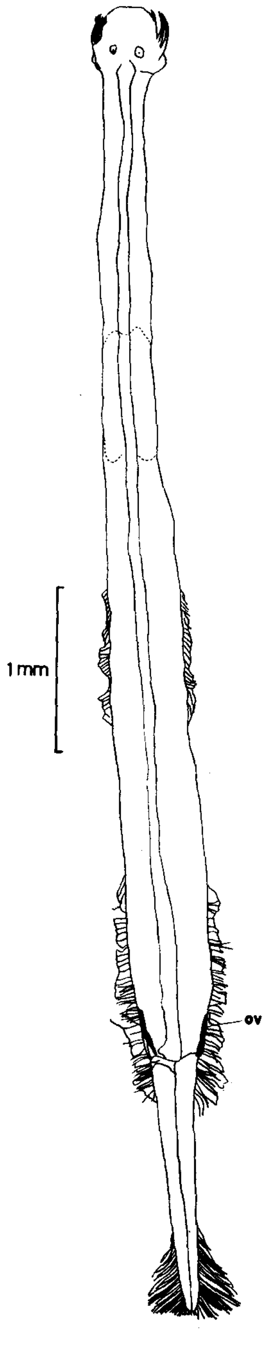

Fig. 27. *Sagitta elegans,* Adult Stage I (8.45 mm long specimen), dorsal view (ov; ovary).

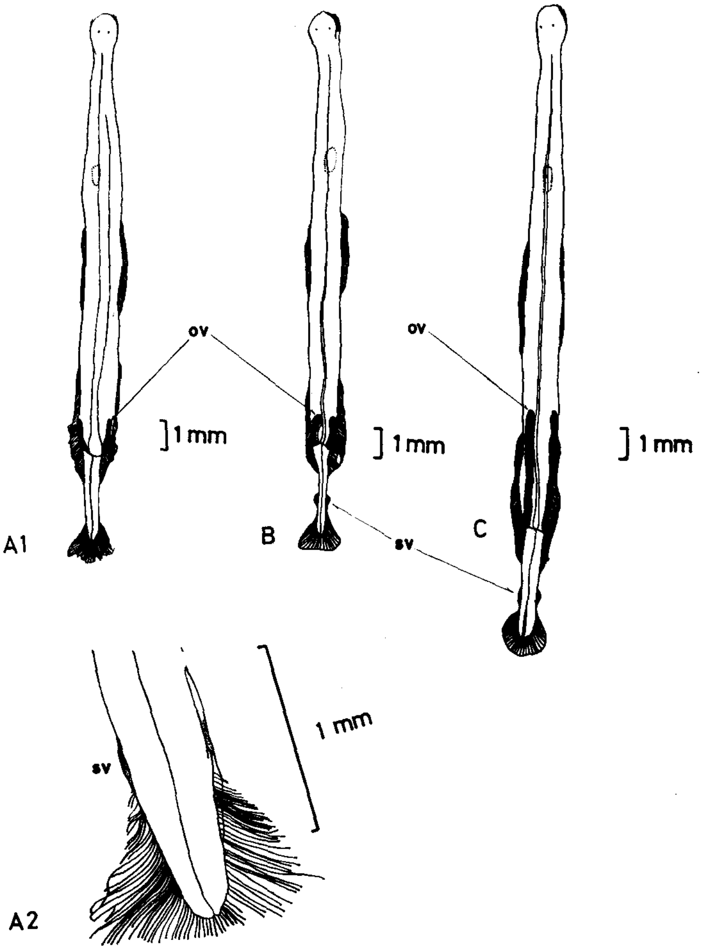

Fig. 28A-C. *Sagitta elegans,* Adult Stage II (ov; ovary. sv; seminal vesicle). A1: Dorsal view of the body (18.20 mm long specimen). A2: Dorsal view of posterior parts of the tail. B: Dorsal view of the body (20.40 mm long specimen). C: Dorsal view of the body (23.90 mm long specimen).

length (Fig. 29, Nos. F77–F83 Animals in Appendix III) had a pair of 11 or 12 hooks in the present study (Fig. 30).

The following 5 stages of development are proposed for the prematuring *Sagitta elegans* according to the developmental processes described above in the present study: (1) Larval Stage I is from newly-hatched larvae to the point when young animals are just about to have their tail septum; less than 1.5 mm in length in the present observation (Fig. 22); (2) Larval Stage II is reached when the animals have their tail septum, but no hooks yet, 1.5–1.7 mm in length (Plate IF); (3) Larval Stage III includes those animals in which a set of 8 hooks appear on the

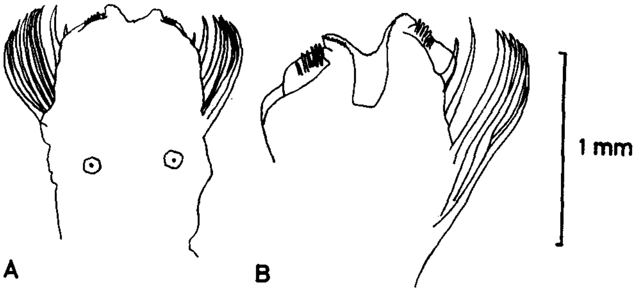

Fig. 30A-B. Head of *Sagitta elegans* (Adult Stage III). A: Dorsal view. B: Ventral view.

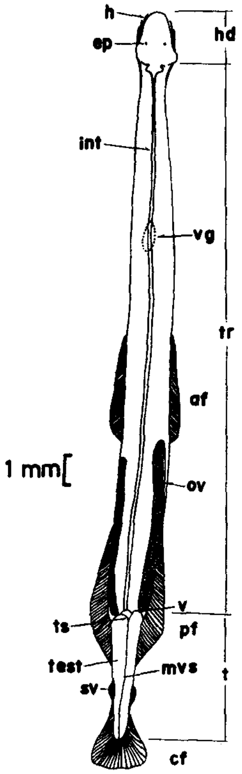

Fig. 29. *Sagitta elegans*, Adult Stage III (25.58 mm long specimen), dorsal view (hd; head. tr; trunk. t; tail. h; hook. ep; eye pigment. int; intestine. vg; ventral ganglion. af; anterior fin. ov; ovary. v; vagina. pf; posterior fin. mvs; median vertical septum. ts; tail septum. test; testis. sv; seminal vesicle. cf; caudal fin).

Table 5. *Proposed developmental stages of*

Developmental stages	Body length (mm)	Percentage of tail length to body length (%)	Number of hooks on one side of head
Larval Stage I	1.2-1.5	—	None
Larval Stage II	1.5-1.7	37.8-45.2	None
Larval Stage III	1.7-2.2	40.2-44.3	8
Juvenile Stage I	2.1-5.0	24.2-45.4	7-8
Juvenile Stage II	5.1-7.9	18.3-25.1	7-8
Adult Stage I	7.9-18.2	15.8-21.2	7-8
Adult Stage II	18.2-27.7	17.3-17.7	7-8
Adult Stage III	23.1<	16.9-18.1	8-12

head, but in which eye pigments have not appeared on the head, and the larvae are 1.7–2.2 mm in length (Figs. 23 and 24); (4) Juvenile Stage I is when animals get eye pigments on the head, but do not have anterior fins; they are from 2.1–5.0 mm in body length (Fig. 25); (5) Juvenile Stage II furnishes a pair of anterior fins, but no sexual products are detected in these animals by microscopic observation, and the juveniles are from 5.1 to 7.9 mm in length (Fig. 26).

For the elder forms of *Sagitta elegans*, the following three stages of maturity were presented by Russell (1932a): his Stage I includes all the youngest animals in which not a single sperm mother cell is seen lying loose in the tail cavity; Stage II ranges between those individuals with the first appearance of spermatocytes and those in which the tail segment is packed with spermatocytes and spermatozoa, but in which the ovaries show little sign of swelling eggs; Stage III includes those individuals in which the ovaries are fully ripe or ripening.

All of the five stages, Larval Stages I-III, Juvenile Stages I and II, proposed in the present study corresponds to Russell's (1932a) Stage I of maturity. *S. elegans* of 7.9–18.2 mm in length with the small ovaries being less than 8% of the length of the ovary in the body length in the present observation corresponds to Russell's (1932a) Stage II. At this stage, seminal vesicles begin to appear on each side of the tail segment in the present observation. According to the present observation, it is suggested that Russell's (1932a) Stage II be divided into two stages. Because, individuals longer than 23 mm in length with fully-developed seminal veiscles had a set of 11 or 12 hooks on the head, while most individuals ranging from 18 to 23 mm in body length had a set of only 7 or 8 hooks, and their seminal veiscles were not fully-developed in the present study. Therefore, it may be suggested that Russell's (1932a) maturity stages II and III be rearranged into the following three stages of development based on the present observation: (1)

Sagitta elegans *through its life span.*

Percentage of ovary length to body length (%)	Height of seminal vesicle from its base (mm)	Anterior fin	Eye pigments	Other remarks
Absent	Absent	Absent	Absent	No trunk-tail septum. Collarette covers large parts of the body.
Absent	Absent	Absent	Absent	Trunk-tail septum is present.
Absent	Absent	Absent	Absent	
Absent	Absent	Absent	Present	
Absent	Absent	Present	Present	
<7.99	Absent	Present	Present	
5.00-20.62	≦0.14	Present	Present	Seminal vesicles are fully matured during the stage.
6.51-24.82	0.15	Present	Present	Number of hooks is almost 11 or 12.

Adult Stage I includes individuals with the first appearance of the ovarian products and those in which there are no seminal vesicles on each side of the tail segment (Fig. 27); (2) Adult Stage II includes those individuals in which the seminal vesicles are developing and in which hooks are only 7 or 8 in number on each side of the head (Fig. 28); and (3) Adult Stage III includes the animals with 11 or 12 hooks on each side of the head and in which the seminal vesicles ripen to the maximum size of 0.15 mm in thickness (Fig. 29). It was suggested in the previous paragraph that the length of the body varied from 7.9 to 18.2 mm in Adult Stage I; 18.2–27.7 mm in Adult Stage II; and it is more than 23.1 mm in Adult Stage III in the present study.

Accordingly, it may be right to conclude that the developmental processes of *Sagitta elegans* are represented by the 8 stages shown in Table 5 in the present study. Quite recently, Reeve and Cosper (in press) noted that a more constant indication of maturity in *S. hispida* was the appearance of seminal vesicles. This view is supported in the case of *S. elegans* so as to divide the maturing phase into Adult Stages I, II and III in the present study. Moreover, Reeve and Cosper (in press) divided the entire life history of *S. hispida* into four stages (Larva, Juvenile, Immature, and Mature) for the sake of convenience. Their classification schemes correspond essentially to those given in the present study.

(2) Respiration

The results of the study on the respiration of *Sagitta elegans* are shown in Table 6 in the present report.

The rate of respiration ranged between 0.196 and 5.989 μl O_2/animal/hour at 2.0–4.0°C, in a total of 16 experiments in the present observation. In the other 8 experiments, the rate was between 0.354 and 6.252 μl O_2/animal/hour at 8.1–14.8°C.

According to Ikeda (1970), the respiration rate in *Sagitta elegans* (1.13–4.83 mg in body dry weight) was 0.827–1.180 μl O_2/animal/hour at 5.3–8.2°C. Sameoto (1972) reported that the rate of respiration of this species in Bedford Basin was 5.1–30.0 μl O_2/animal/24 hours, namely 0.2–1.3 μl O_2/animal/hour at 1.0–16.0°C. Accordingly, on the magnitude of order in the values, these values given by Ikeda (1970) and Sameoto (1972) correspond to those described above in the present study.

The metabolic rate (respiration rate) of organisms is the power function of the body weight (Prosser, 1961; Ikeda, 1974). For instance, this relationship is expressed mathematically as follows;

$$R = aW^{b} \qquad (1),$$

where R is the weight specific respiration rate (μg-at O_2/mg body weight/hr), W is the body dry weight (μg/animal), b is an exponential constant and a is a constant of proportionality. In terms of logarithmic form, equation (1) is rewritten as;

$$\log R = b \cdot \log W + \log a \qquad (2).$$

Fig. 31 shows a scatter diagram of the weight specific respiration rate and the

Table 6. *Respiration rates of* Sagitta elegans *under various experimental conditions.*

Exp. No.	Experimental conditions					Animal dry weight (mg/animal)	Respiration rate	
	Number of animal experimented	Time after capture (days)	Duration of incubation (hours)	Temperature (°C)	Oxygen concentration (ml/l)		(μl O_2/animal/hour)	(μl O_2/mg dry wt/hr)
1	5	2	24	8. 6-11. 0	5. 93	0. 954	1. 428	1. 499
2	5	4	24	9. 2-11. 0	6. 62	0. 936	1. 326	1. 381
3	5	10	48	8. 1-12. 2	6. 06	0. 987	1. 722	1. 743
4	5	13	24	11. 8-14. 8	5. 92	0. 987	1. 753	1. 773
5	5	16	24	2. 0- 4. 0	6. 39	0. 888	0. 224	0. 248
6	5	21	24	3. 5	2. 54	0. 888	0. 700	0. 788
7	6	14	48	2. 0- 3. 0	6. 18	0. 406	0. 805	1. 970
8	5	1	24	3. 0	7. 64	0. 152	0. 196	1. 289
9	5	4	24	3. 0	7. 28	0. 152	0. 476	3. 132
10	4	3	24	3. 0	7. 22	0. 108	0. 319	2. 954
11	4	1	48	3. 0	7. 62	0. 743	1. 744	2. 347
12	3	3	48	3. 0	8. 21	0. 697	1. 688	2. 422
13	5	1	24	3. 0	7. 66	0. 106	0. 448	4. 226
14	3	2	25	3. 0	7. 72	0. 133	1. 239	9. 316
15	3	3	51	3. 0	7. 66	0. 133	0. 469	3. 526
16	1	10	48	13. 0	6. 78	0. 27	6. 252	23. 156
17	5	1	24	3. 0	7. 92	1. 138	1. 111	0. 976
18	5	2	24	3. 0	7. 27	1. 138	0. 710	0. 624
19	4	3	24	3. 0	6. 93	1. 358	1. 575	1. 160
20	3	5	24	3. 0	7. 56	0. 447	5. 989	13. 489
21	3	6	24	3. 0	7. 26	0. 447	1. 167	2. 611
22	5	1	24	13. 0	7. 03	0. 282	0. 813	2. 883
23	5	2	24	13. 0	6. 36	0. 282	1. 343	4. 762
24	5	3	24	13. 0	6. 61	0. 282	0. 354	1. 255
25	5	5	24	3. 0	3. 61	1. 280	10. 089	7. 882
26	6	6	24	13. 0	4. 36	0. 260	1. 789	6. 881

body weight for *Sagitta elegans* with a regression line, which was calculated above in equation (2) on the basis of the results obtained at 2.0–4.0°C in the present study. Then, the equation of regression line was calculated to be

$$\log R = 0.8252 - 0.5990 \log W \quad (r = -0.5703) \qquad (3).$$

The fact that the weight specific respiration rate decreases with the increase in body weight for many zooplankton (Ikeda, 1974) is confirmed for *S. elegans* by equation (3).

(3) Metabolants

If protein alone is being metabolized (45% carbon, 16% nitrogen), approximately 8 atoms of oxygen are proportional to 1 of nitrogen theoretically. As this

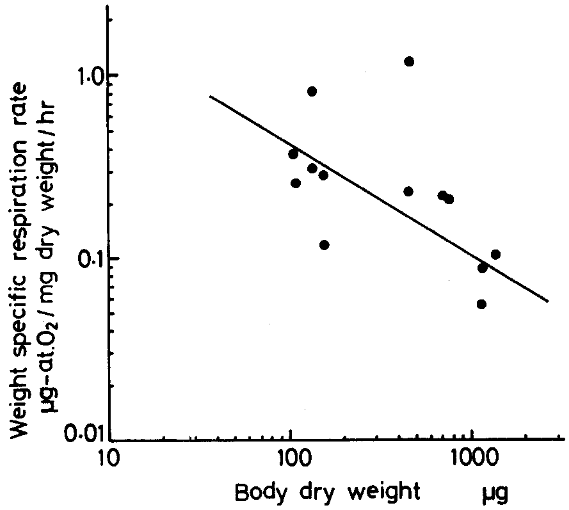

Fig. 31. Relationship between the log weight specific respiration rate and the log body dry weight of *Sagitta elegans*.

protein substrate becomes progressively mixed with non-nitrogen substrates, so the ratio increases, ultimately (where no nitrogen-containing material is involved), to infinity. Therefore, the ratio of oxygen respired and nitrogen excreted by *S. elegans* would be an indication of metabolants of this species.

Ikeda (1974) reported the O:N ratio in *Sagitta elegans* was 7–15, while in a tropical chaetognath *S. hispida*, the O:N ratio was found to be always approximately 7 during either starvation and non-starvation conditions (Reeve et al., 1970). The O:N ratio higher than 7 was also obtained in *S. elegans* during starvation conditions by the present author (Kotori, in preparation).

On the other hand, the highest percentage of protein (dry weight basis) in the body was found in *Sagitta elegans* (84.0%) in the planktonic animals from the Bering Sea in summer; lipid accounts for 6.7% and carbohydrate, 0.7% of the body dry weight of this species (Ikeda, 1972). In the zooplankton other than chaetognaths, carbohydrate is the least of the three constituents of the body (Raymont, 1963). The results obtained by Reeve et al. (1970) on the biochemical composition of *S. hispida* showed that protein constituted about 1/2 of the dry weight (52.9%), with lipid and carbohydrate 17.0 and 3.5%, respectively. Beers (1966) also suggested that carbohydrate was the least of these three constituents of the body, being only 0.31% for mixed species of chaetognaths. All of these described above support the results of Raymont and Krishnaswamy (1960) and Raymont and Conover (1961).

Since the O:N ratio in *Sagitta elegans* was found to be more than 7 by Ikeda (1974) and Kotori (in preparation), and carbohydrate in the body of *S. elegans* was the least of the three constituents as reviewed above and based on previous works, it may be safe to assume that the metabolants of *S. elegans* contain not only protein but also lipid of the body.

In the case of *Sagitta hispida*, however, the fact that the O:N ratio was found to be approximately 7, is indicative of pure protein metabolism (Reeve et al., 1970). It appears that the difference in the source of metabolites found in these two species may be a resultant of the difference in the zoogeographical distribution and metabolic activities between *S. hispida* and *S. elegans*. The former is an inhabitant of the temperate-tropical seas, having a shorter life span than the latter: *S. hispida* takes only 19–45 days to complete its life span according to the rearing experiments at 17–31°C in the laboratory (Reeve, 1970b; Reeve and Walter, 1972); a boreal chaetognath *S. elegans* takes 40–180 days to complete its life span off Plymouth (Russell, 1932a) and 2 years in the Arctic Sea (Dunbar, 1962). Therefore, it is probable that *S. elegans* metabolizes not only its bodily protein but also the lipid preserved in the body so as to endure starvation and survive during the long period of scarce food supply in winter.

(4) Relationship between body dry weight and body length

The correlation diagram of log weight specific respiration rate-log dry weight for *Sagitta elegans* was shown at the experimental temperature of 2.0–4.0°C in Fig. 31 in Section (2) of this Chapter. Therefore, the oxygen consumption of a chaetognath community of *S. elegans* of various sizes could be calculated by only measuring the body length of this species individually collected in the sea, if the relationship between body dry weight and body length of this species were indicated.

Relationship between log body dry weight and log body length of *Sagitta elegans* is illustrated in Fig. 32 in the present study. The equation of regression line was calculated to be

$$\log W = -3.6862 + 2.8500 \log L \quad (r=0.9257) \qquad (4),$$

where L is the body length in mm from the tip of the head to the base of the tail and W is the body dry weight in mg.

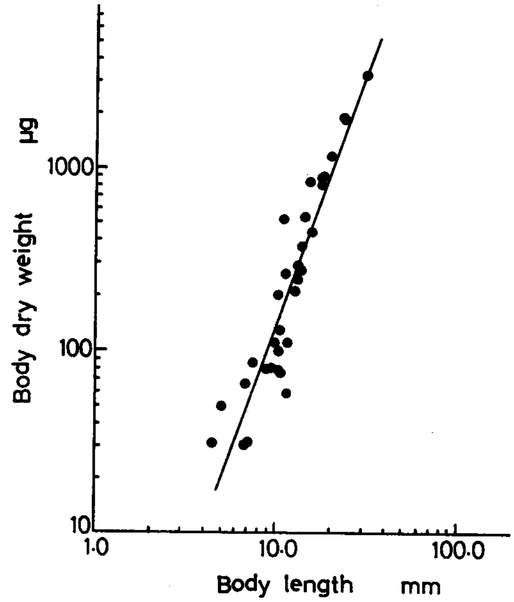

Fig. 32. Relationship between the log body length and the log body dry weight of *Sagitta elegans*.

(5) Conversion from wet weight to the amount of carbon in the mixed species of zooplankton in the subarctic seas

The results of the determination

Table 7. *Wet weight, dry weight, and carbon content of mixed zooplankton collected with Ocean in the summer of 1969. Ratios of dry weight to wet weight and of carbon*

No. of station	Position	Date	Time (LZT)	Volume of water filtered (m^3)
Shark 3	41°01.1′N 165°10.1′E	Aug. 16, 1969	2242-2309	188.2
4	42°32.6′N 171°17.2′E	17	2122-2155	190.7
5	43°46.7′N 176°41.9′E	18	2030-2206	208.1
6	44°57.8′N 176°50.5′W	18′	2232-2303	189.1
7	46°22.3′N 170°35.5′W	19	2122-2156	176.2
8	47°58.0′N 164°08.0′W	20	2212-2242	162.1
9	49°28.1′N 157°30.1′W	21	2226-2254	161.1
10	49°33.7′N 154°31.1′W	27	2006-2044	227.6
11	44°59.8′N 155°02.0′W	28	1909-1938	194.8
12	44°23.5′N 154°59.0′W	29	2007-2039	185.8

of wet and dry weight, total carbon, and nitrogen in the mixed species of zooplankton collected at a total of 10 stations for the present observation in the northern North Pacific Ocean in summer are summarized in Table 7.

The results indicate that the dry-weight/wet-weight ratio ranged from 0.06 to 0.17, and averaged 0.12; the carbon/dry-weight ratio ranged from 0.27 to 0.68, and averaged 0.47 in the present study. Therefore, a factor of 0.06 will be used in the following discussion to convert wet weight to carbon in the mixed species of zooplankton in the present study. Omori's (1969) data suggested that the factor of 0.06 proposed in the present study will be acceptable in converting wet weight to carbon amount in the mixed species of zooplankton in the subarctic seas.

V. Ecological importance of a chaetognath community in the Bering Sea

It is generally recognized that the biological production in the sea occurs in the epipelagic layers (Taniguchi, 1972). This means that the epipelagic layers are a main board of energy flow in the sea. It may be reasonable to think that the oceanic food chain in the epipelagic layers of the Bering Sea involves four trophic levels from the photosynthetic plankton (primary producer) to zooplanktivorous fishes (tertiary consumer).

In the present study, it has been emphasized that *Sagitta elegans*, a member of *a Shark high-speed plankton sampler from the surface in the subarctic North Pacific content to dry weight are also presented.*

Wet weight (g/1000 m^3)	Dry weight (mg/1000 m^3)	Carbon content (mg/1000 m^3)	Dry weight/wet weight ratio	Carbon/dry weight ratio
36.1	3255.48	894.26	0.09	0.27
17.8	2826.32	1183.53	0.15	0.42
23.1	1406.54	575.11	0.06	0.41
9.5	1080.06	306.82	0.11	0.28
37.5	4564.58	2464.59	0.12	0.54
64.1	9661.94	4023.07	0.15	0.42
158.9	14061.84	8387.83	0.09	0.60
105.4	12052.00	5971.88	0.11	0.50
59.5	9219.72	6263.04	0.16	0.68
21.5	3623.48	1992.03	0.17	0.55

the typical carnivorous zooplankton (secondary consumer), was abundantly distributed in the epipelagic layers of the Bering Sea. It will be generally accepted that *S. elegans* plays an important rôle in the energy flow in the sea since it constitutes about 10% of the macrozooplankton biomass in the upper 150-m layers in the Bering Sea, as shown in the present study. However, there have been few attempts to estimate quantitatively the function of *S. elegans* as a secondary consumer.

In this chapter, the ecological importance of a chaetognath community composed of *Sagitta elegans* will be described quantitatively and our research will be based on the data presented previously in this study.

The correlation of log weight specific respiration rate-log dry weight in *Sagitta elegans* at the experimental temperature of 2.0–4.0°C was described in equation (3) as shown in Chapter IV of this text. Needless to say, a population of *S. elegans* consists of individuals of various body weight. Therefore, it is necessary, for the calculation of the oxygen consumption of a chaetognath community composed of a single species of *S. elegans*, to understand the weight composition of the population, which can be estimated by equation (4) described previously in Chapter IV from the measurement of *S. elegans* (Table 8).

It is a common knowledge that the respiration quotient (RQ, CO_2:O_2 ratio in volume) varies with the metabolants from 1.0 to 0.7 (Ashida, 1965). Therefore, the volume of carbon dioxide produced as the result of respiration by the chaetognath community could be estimated if the respiration quotient of *Sagitta elegans*

Table 8. *Composition of the body length of* Sagitta elegans *collected at 24 stations*

No. of station												Standard
	1	2	3	4	5	6	7	8	9	10	11	12
682812	0	1	0	0	0	0	0	0	0	0	0	0
14	142	127	8	1	0	0	0	0	0	0	0	0
15	29	1	1	0	0	0	2	1	2	1	4	0
30	0	0	0	4	0	0	0	0	0	0	0	0
34	26	41	38	38	28	38	51	35	23	21	18	9
36	0	1	0	0	0	0	3	0	1	0	0	0
37	0	0	5	15	61	83	58	56	46	33	27	14
39	0	11	8	11	7	0	1	4	1	0	3	2
40	0	0	1	1	1	0	0	0	0	0	0	5
41	0	1	2	4	0	1	1	0	0	0	0	1
50	0	1	6	12	25	23	30	40	28	26	19	15
61	0	5	13	16	36	23	35	30	34	34	34	31
62	0	0	3	26	42	43	33	21	30	53	44	59
63	0	1	12	51	85	74	46	17	26	17	9	14
64	0	13	87	185	199	158	89	41	20	13	2	1
67	17	32	22	29	64	77	90	78	72	37	15	11
68	0	12	33	40	45	39	26	23	5	1	0	0
69	1	6	15	10	19	11	1	1	0	0	0	0
70	1	0	2	6	20	28	26	27	12	16	4	2
71	1	6	29	56	57	23	10	1	3	3	0	0
74	4	11	12	9	6	6	8	6	1	17	8	10
75	0	0	0	0	2	3	2	1	0	0	0	0
76	0	2	16	28	38	51	45	17	4	6	3	3
78	0	2	2	4	8	6	13	5	5	3	2	1

were defined. By the way, it is also generally accepted that carbon, a component of the organic matter taken by an animal as its food and source of energy, is to be released wholly in the form of carbon dioxide as the result of respiration (Ashida, 1965). It is therefore reasonable that the oxygen consumption should be converted into carbon utilization (Menzel and Ryther, 1961).

In the present study, the tentative estimation of carbon requirement by a chaetognath community composed of a single species of *Sagitta elegans* in the eastern Bering Sea in summer conduces to emphasize the ecological importance of the chaetognath community in the boreal waters, on the assumption that the metabolant of *S. elegans* is mainly composed by lipid, so that the respiration quotient is fitted to be 0.7 of lipid metabolism. Moreover, the calculation was undertaken on the assumption that the environmental temperature of the habitat of this species in the eastern Bering Sea was 2.0–4.0°C, since the experiments on the relationship between respiration and body weight of *S. elegans* were carried out at 2.0–4.0°C. Therefore, the present result of the calculation for the carbon requirement of this species shown in Table 9 appears to be somewhat underestimated, because the environmental temperature was actually a little higher than the experimental temperature of 2.0–4.0°C in some cases.

According to this estimation (Table 9), a chaetognath community composed of a single species of *Sagitta elegans* in the eastern Bering Sea in summer required 0.01–15.17 mg C/m^2/day, averaged 4.71 mg C/m^2/day. It is noteworthy that the *in the eastern Bering Sea in the summer of 1968 (individuals per haul).*

length (mm)														
13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
0	0	0	0	0	1	1	0	0	0	0	0	0	0	0
0	2	2	0	4	1	0	1	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	1	0	0	1	1	1	3	6	6	6	2	2	1	1
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	1	4	2	3	0	0	4	7	6	2	2	2	0	0
4	5	9	10	5	1	4	2	0	0	1	0	0	0	0
0	2	3	1	1	0	0	3	0	0	0	0	0	0	0
4	0	12	12	12	14	11	6	4	3	2	0	2	0	0
3	5	2	2	4	3	2	2	2	2	0	1	0	0	1
37	26	14	7	9	6	4	3	2	8	6	5	6	0	0
55	43	33	24	9	9	5	8	6	3	0	2	1	0	0
8	10	16	14	19	16	8	11	6	3	1	0	1	0	0
3	3	9	6	15	19	12	26	14	10	6	4	5	0	1
0	0	0	1	0	0	1	0	2	1	0	0	0	0	0
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	0	0	1	0	0	0	0	0	0	0	0	0	0	0
0	1	0	1	0	0	0	1	0	0	0	0	0	0	0
0	7	6	4	8	14	4	8	0	2	2	2	1	0	0
7	4	5	8	6	6	5	1	1	2	1	1	0	1	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	1	2	0	1	5	0	0	0	0	1	0	1	0	0
0	0	0	1	1	0	0	0	0	0	0	0	0	0	0

calculation of the value was based on the experimental results obtained not only under a temperature somewhat lower than that of the actual environment of the eastern part of the Bering Sea, but also under starvation. It is evident that the value reflects the basal metabolisms of *S. elegans*. Therefore, it may be safe to assume that the estimated results represent the basal and minimum carbon requirement of the chaetognath community in the epipelagic layers in the eastern part of the Bering Sea in summer.

It is reported that the primary productivity in the euphotic layers of the Bering Sea in summer was 490 mg C/m^2/day (Taniguchi, 1972); consequently, the carbon requirement of a chaetognath community tentatively calculated here (4.71 mg C/m^2/day) corresponds to about 1% of the primary productivity. On the other hand, the macrozooplankton biomass other than chaetognaths in the epipelagic domain in the eastern part of the Bering Sea was recorded to be 32.2–2,682.7 g wet weight/1,000 m^3 in the present study (Appendix IV), averaged 2,689.4 mg C/m^2 using the conversion factor of 0.06 previously indicated (see, pp. 141–142). Therefore, the daily carbon requirement (4.71 mg C/m^2) corresponds to about 0.2% of the macrozooplankton biomass other than chaetognaths in the eastern part of the Bering Sea.

Moreover, if the 10% of the ecological efficiency factor is adopted in the Bering Sea (Ryther, 1969), the secondary productivity of the Bering Sea in

Table 9. *Respiration rate and carbon requirement of a chaetognath community in the eastern Bering Sea in the summer of 1969.*

No. of station	Maximum depth of collection (m)	Respiration by a chaetognath community (μl O_2/1000 m^3/hr)	Carbon required by a chaetognath community		
			(mg/m^3/hr)	(mg/m^2/hr)	(mg/m^2/day)
682812	139	59.16	0.000022	0.003058	0.07
14	90	1975.64	0.000743	0.066870	1.60
15	68	2031.72	0.000761	0.051748	1.24
30	40	28.76	0.000011	0.000440	0.01
34	83	16034.73	0.006011	0.498913	11.97
36	110	110.07	0.000041	0.004510	0.11
37	87	19372.90	0.007264	0.631968	15.17
39	65	5298.05	0.001988	0.129220	3.10
40	45	7426.04	0.002786	0.125370	3.01
41	52	13077.26	0.004905	0.255060	6.12
50	82	8527.44	0.003199	0.262318	6.30
61	103	10927.87	0.004099	0.422197	10.13
62	83	15157.85	0.005685	0.471855	11.32
63	75	4417.43	0.001658	0.124350	2.98
64	67	18557.39	0.006960	0.466320	11.19
67	44	29097.24	0.010913	0.480172	11.52
68	35	7763.22	0.002910	0.101850	2.44
69	30	3159.03	0.001185	0.035550	0.85
70	44	8999.00	0.003375	0.148500	3.56
71	50	11598.85	0.004350	0.217500	5.22
74	106	2526.32	0.000949	0.100594	2.41
75	96	82.51	0.000030	0.002880	0.07
76	84	2977.42	0.001118	0.093912	2.25
78	92	511.99	0.000191	0.017572	0.42

Table 10. *Primary productivity, secondary productivity, and amount of carbon required by a chaetognath community in the Bering Sea in summer.*

Primary productivity (observed, Taniguchi, 1972)	490 mg C/m^2/day
Secondary productivity (estimated, present study*)	49 mg C/m^2/day
Amount of carbon required by chaetognath community (calculated, present study)	4.71 mg C/m^2/day

* 10% of ecological efficiency factor is adopted.

summer can be calculated from the primary productivity of 490 mg C/m^2/day to be 49 mg C/m^2/day. This value corresponds to 10 times that of the carbon required by a chaetognath community in the area. It can be emphasized here that the carbon requirement of a chaetognath community corresponds to about 10% of the secondary productivity in the Bering Sea in summer (Table 10). This strongly suggests that chaetognaths play an essential rôle as a secondary consumer in the energy flow of the seas.

VI. Summary

(1) The biology of chaetognaths in the Bering Sea and the northern North Pacific Ocean in summer was investigated in order to ascertain the hypothesis that chaetognaths play an important rôle in the food webs in the sea: first, the areal and the vertical distribution of chaetognath species in the actual area were investigated quantitatively, and the relationship between the distribution and its limiting factors was discussed; second, the developmental processes of *Sagitta elegans*, which are suggested to be the most dominant chaetognath in the epipelagic layers in the present area, were examined, and the rates of respiration in this species were determined; and finally the rôle played by a chaetognath community in the epipelagic layers was discussed on the basis of the tentative estimation of carbon requirement of the community in the eastern part of the Bering Sea in summer.

(2) Out of a total of 214 samples collected by 0–m to 150–m vertical hauls with a Norpac net and by simultaneous horizontal tows to a depth of about 500 m with several MTD 56–cm closing nets, the following 17 species in 4 genera of chaetognaths were identified: *Sagitta enflata* Grassi, *S. hexaptera* d'Orbigny, *S. lyra* Krohn, *S. scrippsae* Alvariño, *S. maxima* (Conant), *S. elegans* Verrill, *S. nagae* Alvariño, *S. pacifica* Tokioka, *S. neglecta* Aida, *S. minima* Grassi, *S. neodecipiens* Tokioka, *S. zetesios* Fowler, *S. macrocephala* Fowler, *Pterosagitta draco* (Krohn), *Eukrohnia hamata* (Möbius), *E. bathypelagica* Alvariño, and *Krohnitta subtilis* (Grassi). In the upper 150 m of the present area, *Sagitta elegans* is distributed most abundantly and widely. The average number of individuals was 10,000/1,000 m^3 throughout 168 stations. *Eukrohnia hamata* was next to *S. elegans* in abundance in the upper 150 m in most parts of the present area. Its average number of individuals was 2,000/1,000 m^3 throughout 168 stations for the present sampling.

(3) *Sagitta elegans* appeared most abundantly in the eastern part of the Bering Sea (25,000 individuals/1,000 m^3 on the average through 52 stations), where *Eukrohnia hamata* did not appear. This shows a marked contrast between the two species in their areal distribution in the Bering Sea. *S. elegans* was also distributed abundantly in the area off the eastern coast of Kamchatka, the Kurile Islands, and Hokkaido. It appeared to be relatively abundant in the southern coastal waters along the Aleutian Islands. On the other hand, this species decreased rapidly in the southern region beyond the latitude of 50°N in the central parts of the northern North Pacific Ocean. This fact suggests that the species is a typical biological indicator for the Subarctic Water. It was confirmed that *S. elegans* is epiplanktonic with the maximum abundance in the upper 25 m, and that it mainly consists of small individuals less than 10 mm in length, and with a marked secondary concentration at a depth of 100–200 m in the subarctic waters, although this species may range to a denth of 700 m in the present area.

(4) *Eukrohnia hamata* was somewhat more abundant off the eastern coast of the Kamchatka Peninsula and the Kurile Islands than in the other parts of the present area. However, this species did not appear in the eastern part of the

Bering Sea. Vertically, the maximum abundance of this species in the daytime was found at 190 m at 50°N, at 320 m at 45°N, and below 580 m at 40°N. This confirms the fact that the species is distributed in the deeper waters in the lower latitudes.

(5) It was suggested that salinity was one of the possible factors controlling the distribution of *Sagitta elegans* because of its low salinity preference, whereas temperature probably affects the distribution of *Eukrohnia hamata,* because the upper limit of the vertical distribution of this mesoplanktonic species corresponded to the 8°C contour of the temperature profile. The results of the field observations and a preliminary experiment in the land laboratory suggest that the low dissolved oxygen contents have less effect than the increase in temperature as a limiting factor of distribution of *S. elegans.*

(6) The distributions of *Sagitta lyra, S. scrippsae, S. minima,* and *S. nagae* were all limited zoogeographically to the south of 49°N in the present area, where *S. elegans* occurred only in small numbers. *S. lyra* predominated sometimes in the southernmost parts of the present area. *S. maxima* was collected only once from the northern part of the Bering Sea in the present samplings. *S. pacifica, S. neglecta* and *Pterosagitta draco* appeared only in the North Pacific Central Water. Vertically, it was recognized that *S. scrippsae* and *S. minima* were distributed from the epipelagic layers to the upper domain of the mesopelagic layers, and that *Eukrohnia bathypelagica* was below 150–200 m in the subarctic waters. *Sagitta macrocephala* and *S. zetesios* were suggested to have their habitat below 500–600 m deep. Some information on the depth preference of *S. lyra, S. hexaptera, S. nagae, S. enflata, S. neodecipiens* and *Krohnitta subtilis* is also presented.

(7) Large amounts of the total number of chaetognaths, more than 10 g wet weight/1,000 m^3, occurred in the eastern part of the Bering Sea, in the area off the eastern coast of Kamchatka, the Kurile Islands and Hokkaido, and in the southern coastal waters along the Aleutian Islands. The chaetognath biomass sometimes counted up to 40–180 g wet weight/1,000 m^3. Moreover, *Sagitta elegans* was the most important constituent of chaetognaths in biomass in the upper 150 m of the present area.

(8) The maximum abundance of the total chaetognath biomass was vertically at a depth of 100 to 300 m, where *Eukrohnia hamata* was predominant. A marked secondary concentration of biomass was at 25 to 100 m, where *Sagitta elegans* was predominant. In the upper 150 m, the fraction of the total chaetognath biomass compared to the whole zooplankton weight was put as an average of 8.1% through 87 stations in the Bering Sea, and 9.5% through 76 stations in the northern North Pacific Ocean.

(9) The following 8 stages of development are proposed for *Sagitta elegans* through its life span: 1) Larval Stage I is from newly-hatched larvae to the young animals just prior to have their tail septum, less than 1.5 mm in body length, from the tip of the head to the base of the tail; 2) Larval Stage II takes in the animals having their tail septum, but not having any hooks, 1.5–1.7 mm in body length; 3) Larval Stage III includes those animals in which a set of 8 hooks first appear on the head, but have no eye pigments on the head; the larvae are

1.7–2.2 mm in body length; 4) Juvenile Stage I is when animals get eye pigments on the head, but do not have anterior fins; they are 2.1–5.0 mm in body length; 5) Juvenile Stage II furnishes a pair of anterior fins, but no sexual products are detected yet in these animals by a microscopic observation, and the animals are 5.1–7.9 mm in body length; 6) Adult Stage I includes individuals with the first appearance of the ovarian products and those in which there are no seminal vesicles on each side of the tail segment, and the length of the body varied from 7.9 to 18.2 mm; 7) Adult Stage II includes those individuals in which seminal vesicles are developing and in which hooks are only 7–8 in number on both sides of the head; the length of the body is 18.2–27.7 mm; 8) Adult Stage III includes the animals with 11–12 hooks on both sides of the head and in which the seminal vesicles were ripened to the maximum size of 0.15 mm in thickness, and it is more than 23.1 mm in length of the body.

(10) For *Sagitta elegans* with W μg dry weight at the habitat temperature of 2.0–4.0°C, the respiration rate R (μg-at O_2/mg body dry weight/hour) is given as; $\log R = 0.8252 - 0.5990 \log W$. Meanwhile, for *S. elegans* with L mm in body length from the tip of the head to the base of the tail, the body dry weight W mg is given as; $\log W = -3.6862 + 2.8500 \log L$. Therefore, the oxygen consumption of a chaetognath community consisting of individuals, different in body size, of a single species of *S. elegans* can be calculated with these two equations only from the measurement of the length composition of *S. elegans* in the community.

(11) It was assumed that the metabolant of *Sagitta elegans* contains not only protein but also lipid of the body. Therefore, the oxygen consumption by a chaetognath community composed of a single species of *S. elegans* can be converted into carbon utilization on the basis of the assumption that the metabolant of *S. elegans* is mainly composed of lipid, and that the respiration quotient is fitted to be 0.7 of lipid metabolism.

(12) The tentative estimation suggests that a chaetognath community composed of a single species of *Sagitta elegans* in the eastern part of the Bering Sea in summer requires 0.01–15.17 mg C/m^2/day, averaged 4.71 mg C/m^2/day. This corresponds to about 1% of the primary productivity, and about 10% of the secondary productivity in the area, so as to emphasize the ecological importance of the chaetognath community in the boreal waters. Moreover, it is suggested that the daily carbon requirement (4.71 mg C/m^2) by a chaetognath community corresponds to about 0.2% of the macrozooplankton biomass (other than chaetognaths) in the eastern part of the Bering Sea in summer.

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Explanation of Plate I

ABBREVIATIONS

hd; head. co; collarette. tr; trunk. vg; ventral ganglion. pf; posterior fin. h; hook. ts; tail septum.

A. Eggs of *Sagitta elegans* spawned under artificial conditions in laboratory (photographed by Dr. T. Ikeda).

B. Newly-hatched larva of *Sagitta elegans* (Larval Stage I), dorsal view (see also Fig. 22 in the text).

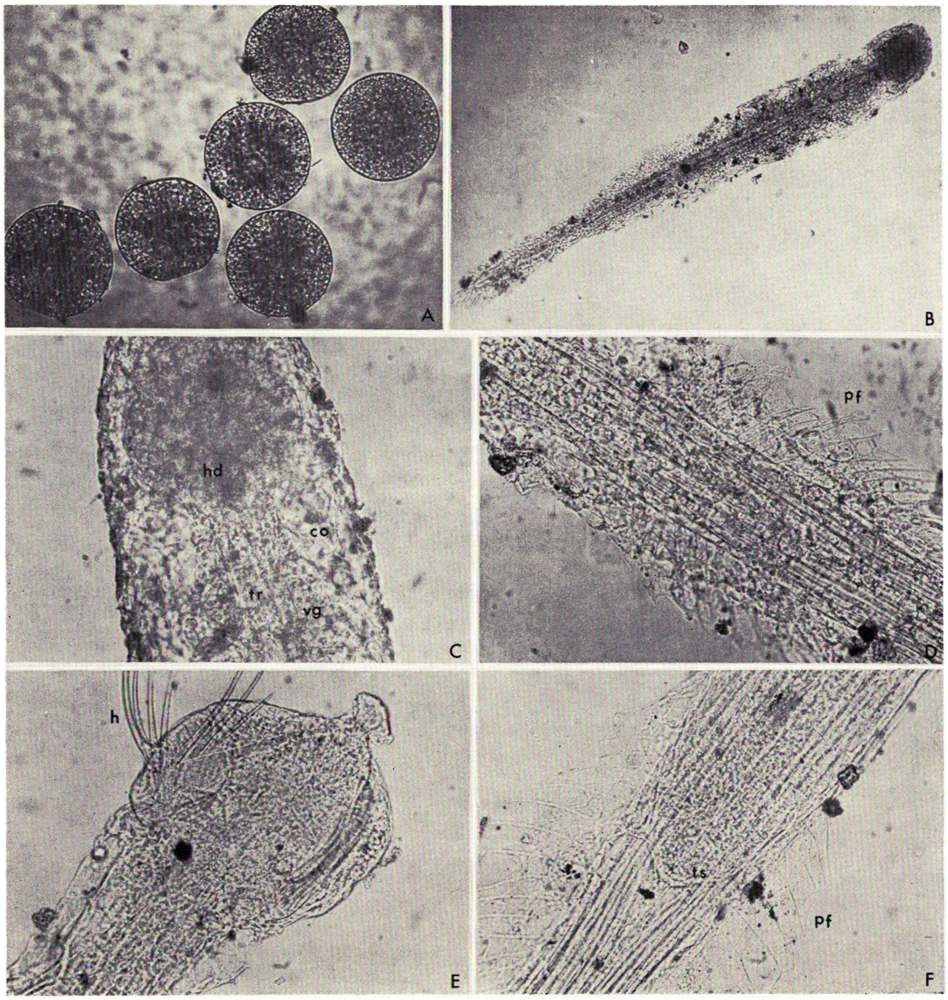
C. Dorsal view of the head and trunk of a two-day old larva (Larval Stage I) of *Sagitta elegans*; eyes and hooks are not developed.

D. Posterior portion of the trunk in the same specimen shown in figure C; the tail septum is not developed yet.

E. Eight-day old larva of *Sagitta elegans* (1.94 mm long specimen, Larval Stage III), dorsal view of the head.

F. Tail septum just appeared in Larval Stage II of *Sagitta elegans* (1.47 mm long specimen).

PLATE I



KOTORI: Biology of Chaetognatha

Appendix IA. *Data on zooplankton sampling with a Norpac net at 168 stations in the Bering Sea and northern North Pacific Ocean.*

No.	No. of station	Position	LZT		Estimated depth of haul (m)	Volume of water filtered (m³)	Wet weight of sample (g/1000 m³)
			Date	Time			
1	573901	46°01′N 154°00′E	Aug. 26, 1957	1410	—	24.0	216
2	02	46°01′ 156°00′	27	0400	—	20.4	255
3	03	46°01′ 158°00′	28	0710	—	24.0	83
4	04	46°00′ 160°00′	28	0825	—	25.8	147
5	05	46°10′ 161°58′	28	2030	—	24.9	92
6	06	46°00′ 164°00′	29	0725	—	28.3	49
7	07	46°00′ 166°00′	29	1810	—	28.5	10
8	08	46°00′ 168°00′	30	0545	—	26.4	41
9	09	46°00′ 170°00′	30	1700	—	36.1	8
10	11	46°00′ 174°00′	31	1300	—	28.2	39
11	13	44°00′ 174°00′	Sept. 1	1020	—	26.9	26
12	16	44°00′ 168°32′	4	1015	—	22.9	39
13	17	44°00′ 166°00′	5	0730	—	47.2	6
14	19	43°49′ 162°00′	6	1300	—	29.4	34
15	20	44°00′ 159°58′	7	0330	—	20.8	58
16	21	44°00′ 158°00′	7	1500	—	30.7	13
17	22	43°41′ 155°41′	9	2000	—	45.3	154
18	23	43°41′ 154°00′	10	0800	—	36.2	39
19	24	43°41′ 152°00′	10	1900	—	26.3	150
20	594401	42°00′ 146°00′	June 9, 1959	1640	146	20.7	614
21	02	42°55′ 146°47′	10	0535	120	26.2	543
22	03	44°04′ 149°40′	10	2025	135	21.7	233
23	04	45°03′ 151°32′	11	0855	130	20.7	625
24	05	46°00′ 153°15′	11	2025	136	30.4	158
25	06	46°35′ 154°50′	12	0835	117	19.3	522
26	07	48°00′ 156°59′	June 12	2335	129	29.9	244
27	08	48°00′ 159°13′	13	1040	121	24.8	350
28	09	48°00′ 161°29′	13	2305	143	31.0	128
29	10	47°42′ 163°31′	14	1635	130	21.3	150
30	11	48°00′ 165°46′	15	1915	138	30.2	86
31	12	48°00′ 168°00′	16	0700	129	13.5	126
32	14	49°40′ 170°00′	17	0645	108	27.6	769
33	15	51°43′ 171°20′	18	1010	121	31.9	85
34	16	53°14′ 171°20′	18	0050	145	21.0	445

Appendix IA. Continued.

No.	No. of station	Position	LZT		Estimated depth of haul (m)	Volume of water filtered (m³)	Wet weight of sample (g/1000 m³)
			Date	Time			
35	594440	57°01′N 174°30′W	July 8, 1959	1650	147	20.4	174
36	41	57°00′ 176°22′	9	0220	141	23.2	19
37	42	57°00′ 179°10′	9	1420	143	23.4	270
38	43	57°38′N 177°59′E	11	1150	130	26.4	461
39	44	57°32′ 176°30′	11	2035	134	24.2	404
40	45	56°56′ 174°30′	12	2050	106	33.6	820
41	46	58°19′ 174°50′	13	1445	123	27.0	527
42	47	58°54′ 172°07′	14	0350	136	28.1	663
43	48	59°19′ 170°20′	14	1135	118	27.0	693
44	49	58°18′ 169°58′	14	2125	144	21.4	771
45	50	57°19′ 169°58′	15	1155	148	17.6	852
46	51	56°22′ 169°58′	15	2135	150	19.9	407
47	52	56°20′ 168°03′	16	1150	136	20.4	328
48	53	56°20′ 166°18′	16	2010	137	20.2	634
49	54	56°29′ 164°21′	17	0415	132	23.2	474
50	55	55°29′ 164°20′	17	1415	129	22.0	41
51	56	54°55′ 164°20′	17	2045	145	20.3	438
52	57	53°54′ 164°16′	18	1235	150	17.4	201
53	58	53°02′ 164°16′	18	2035	147	18.1	44
54	60	51°02′ 164°18′	19	2030	142	23.1	82
55	61	51°11′ 162°48′	20	1215	147	19.6	122
56	62	51°11′ 161°23′	20	2055	124	24.0	92
57	64	50°35′ 159°00′	21	2025	146	17.6	148
58	65	49°35′ 159°00′	22	1230	126	20.8	483
59	66	48°35′ 159°00′	22	2030	150	24.0	—
60	67	47°43′ 157°10′	23	0835	136	18.9	376
61	604601	46°42′ 159°55′	June 11, 1960	0900	150	26.4	507.6
62	02	47°10′ 161°16′	11	2015	150	18.6	247.3
63	03	48°09′ 164°02′	12	2000	145	21.6	46.3
64	04	48°38′ 165°58′	13	0950	157	36.4	35.7
65	05	49°06′ 167°33′	13	2025	149	20.0	10.0
66	07	52°00′ 170°10′	15	1920	152	25.7	163.4
67	08	53°44′ 170°10′	16	0945	168	24.9	269.1
68	09	55°00′ 170°30′	16	2055	153	23.7	122.4

Appendix IA. Continued.

No.	No. of station	Position	LZT		Estimated depth of haul (m)	Volume of water filtered (m³)	Wet weight of sample (g/1000 m³)
			Date	Time			
69	604610	57°00′N 170°30′E	June 17, 1960	1955	152	28. 2	290. 8
70	11	57°00′ 175°03′	18	1500	152	25. 7	540. 9
71	12	55°03′ 175°07′	19	2055	152	14. 4	319. 4
72	13	53°00′ 175°05′	20	2020	149	20. 0	455. 0
73	14	53°05′ 178°05′	21	1945	145	25. 4	594. 5
74	15	52°40′N 179°48′W	21	0955	170	37. 8	108. 5
75	16	52°36′ 179°09′	21	1830	168	37. 1	301. 9
76	17	52°54′ 178°54′	22	1445	150	24. 3	209. 9
77	18	51°00′ 179°31′	23	2110	152	23. 7	329. 1
78	19	49°58′ 179°32′	24	0515	149	20. 2	123. 8
79	20	49°01′ 179°25′	24	1345	148	21. 4	205. 6
80	21	48°16′ 179°32′	24	1932	149	19. 3	72. 5
81	22	48°19′ 176°45′	25	1030	147	24. 9	176. 7
82	23	48°25′ 175°11′	25	1935	147	29. 4	227. 9
83	24	48°22′ 172°00′	26	1418	147	27. 2	161. 8
84	25	48°59′ 171°59′	26	2145	147	28. 9	214. 5
85	26	50°01′ 171°59′	27	0635	150	26. 3	254. 8
86	27	51°16′ 171°56′	27	1818	147	26. 0	326. 9
87	28	53°31′ 171°58′	28	0940	147	23. 0	291. 3
88	29	55°30′ 171°52′	29	1620	148	20. 9	210. 5
89	30	56°00′ 171°44′	30	1605	150	24. 0	504. 2
90	31	57°40′ 171°50′	July 1	1645	89	11. 0	772. 7
91	32	57°41′ 174°25′	2	1755	144	30. 8	172. 1
92	33	58°59′ 173°32′	5	1830	99	18. 8	271. 3
93	34	61°01′ 173°39′	6	1155	70	11. 9	92. 4
94	35	61°00′ 170°00′	6	1935	50	7. 5	226. 7
95	36	59°58′ 170°00′	7	1325	40	5. 6	107. 1
96	37	59°25′ 169°12′	7	1850	40	5. 9	406. 8
97	38	58°43′ 167°54′	8	0850	38	6. 5	107. 7
98	39	58°25′ 166°23′	11	1320	40	4. 7	127. 7
99	40	58°10′ 164°42′	11	2118	40	4. 9	326. 5
100	41	57°46′ 162°01′	12	2020	40	4. 1	170. 7
101	42	56°50′ 163°04′	13	1322	65	6. 3	333. 3
102	43	56°04′ 163°56′	13	2120	81	9. 9	40. 4

Appendix IA. Continued.

No.	No. of station	Position	LZT		Estimated depth of haul (m)	Volume of water filtered (m³)	Wet weight of sample (g/1000 m³)
			Date	Time			
103	604644	55°07′N 164°59′W	July 14, 1960	0600	98	17. 6	85. 2
104	45	54°05′ 163°34′	14	1910	101	14. 3	21. 0
105	46	54°15′ 160°40′	15	0918	150	19. 8	237. 4
106	47	54°14′ 158°37′	15	2025	150	19. 3	253. 9
107	48	54°39′ 156°02′	16	1922	150	20. 0	395. 0
108	49	55°07′ 153°25′	17	0940	149	27. 0	255. 6
109	50	55°54′ 149°24′	18	1118	150	26. 6	872. 2
110	51	56°52′ 145°22′	19	0900	150	21. 4	4. 7
111	52	48°14′ 146°32′	Aug. 10	1637	150	21. 6	304. 8
112	53	43°09′ 170°30′	16	1620	149	18. 8	154. 3
113	54	42°09′ 179°42′	18	1630	150	26. 3	148. 3
114	682805	53°30′ 178°30′	June 13, 1968	1720	—	52. 8	278. 5
115	06	54°30′ 178°30′	14	0105	—	47. 5	570. 5
116	07	55°30′ 178°30′	14	1000	—	46. 8	386. 7
117	10	58°26′ 178°31′	16	0020	—	41. 4	1032. 7
118	11	59°30′ 178°30′	16	0920	—	30. 0	356. 8
119	12	59°26′ 176°29′	17	1300	139	20. 2	714. 3
120	13	59°18′ 174°30′	17	2014	—	15. 4	1115. 4
121	14	59°07′ 172°00′	18	0441	90	9. 4	1246. 0
122	15	58°59′ 169°57′	18	1230	68	7. 5	—
123	16	58°08′ 172°00′	18	2030	—	13. 7	1700. 7
124	17	57°27′ 173°29′	19	0350	—	16. 2	1380. 8
125	18	56°27′ 172°01′	19	1030	—	9. 7	2154. 6
126	20	55°59′ 174°02′	20	1200	—	31. 3	1513. 1
127	21	55°00′ 171°59′	20	2220	—	43. 8	1538. 3
128	24	54°55′ 168°45′	21	2100	—	28. 9	1101. 5
129	25	55°30′ 168°28′	22	1130	—	47. 1	148. 6
130	28	58°00′ 168°30′	23	0630	—	10. 8	499. 5
131	29	59°00′ 168°32′	23	1310	—	2. 7	—
132	30	58°47′ 166°52′	23	1830	40	1. 2	—
133	32	57°31′ 164°59′	24	0715	—	6. 3	571. 4
134	33	57°00′ 164°44′	24	1120	—	8. 3	216. 4
135	34	56°26′ 164°52′	24	2100	83	9. 3	813. 7
136	35	55°55′ 165°07′	25	1130	—	15. 4	921. 5

Appendix IA. Continued.

No.	No. of station	Position		LZT		Estimated depth of haul (m)	Volume of water filtered (m³)	Wet weight of sample (g/1000 m³)
				Date	Time			
137	682836	54°59′N	164°59′W	June 25, 1968	1715	110	14.7	260.6
138	37	55°50′	163°00′	26	0220	87	10.1	2779.4
139	39	57°02′	163°02′	26	1100	65	9.2	248.9
140	40	57°50′	163°00′	26	1600	45	1.8	—
141	41	57°30′	163°00′	26	2030	52	7.1	566.6
142	50	56°35′	164°59′	July 3	1340	82	14.4	1183.8
143	51	58°13′	137°32′	14	0630	115	26.3	110.1
144	52	57°57′	137°10′	14	1000	185	33.6	74.3
145	53	59°04′	139°48′	15	0630	100	15.6	—
146	54	58°52′	139°52′	15	1100	152	35.1	—
147	56	58°32′	139°36′	16	1030	—	30.6	65.3
148	57	59°25′	141°10′	17	0630	173	39.2	198.9
149	58	59°25′	146°58′	18	1700	—	31.0	239.1
150	59	58°50′	149°03′	19	0615	185	26.2	1078.9
151	60	55°00′	164°58′	26	1600	—	22.9	187.5
152	61	55°52′	164°54′	26	2245	103	20.9	478.0
153	62	56°30′	164°58′	27	1500	83	21.4	897.2
154	63	67°00′	165°00′	27	1900	75	50.8	554.7
155	64	57°30′	165°00′	27	2200	67	19.9	371.3
156	67	60°00′	169°00′	31	0630	44	6.7	599.7
157	68	61°00′	168°27′	Aug. 1	1230	35	7.7	365.1
158	69	62°00′	167°59′	1	1800	30	6.5	201.2
159	70	62°14′	170°00′	2	1045	44	6.3	603.2
160	71	62°30′	172°00′	2	1645	50	8.9	269.1
161	73	61°30′	175°00′	4	1215	91	7.3	—
162	74	62°01′	176°31′	4	1730	106	31.9	122.3
163	75	63°01′	177°00′	5	1230	96	30.5	32.8
164	76	63°00′	175°00′	5	1900	84	26.3	136.7
165	77	63°50′	175°00′	6	0030	—	21.6	306.0
166	78	63°50′	177°00′	6	0530	92	38.7	95.7
167	79	63°49′	179°01′	6	1110	—	22.4	152.1
168	80	63°00′	179°01′	7	0445	—	69.9	527.7

Appendix IB. *Full data on chaetognath species collected by vertical hauls with a Norpac net Ocean during four summer cruises of "Oshoro Maru" in 1957, 1959, 1960 and*

No.	No. of station	Wet weight of sample (g/1000 m^3)	Wet weight of chaetognaths (g/1000 m^3)	Percentage of weight of chaetognaths to whole zooplankton (%)	Individuals			
					Sagitta lyra	*S. scrippsae*	*S. maxima*	*S. elegans*
1	573901	216	47.7	22.1	0	0	0	7958
2	02	255	12.0	4.7	0	0	0	4853
3	03	83	8.0	9.6	0	0	0	3542
4	04	147	11.0	7.5	0	0	0	2403
5	05	92	11.2	12.2	121	40	0	1487
6	06	49	5.2	10.6	459	35	0	2014
7	07	10	—	—	70	0	0	281
8	08	41	2.1	5.1	114	0	0	341
9	09	8	0.6	7.5	0	0	0	55
10	11	39	2.6	6.7	142	0	0	674
11	13	26	1.3	5.0	223	0	0	149
12	16	39	2.8	7.2	0	0	0	349
13	17	6	0.2	3.3	21	21	0	42
14	19	34	2.1	6.2	442	0	0	1701
15	20	58	4.2	7.2	0	0	0	529
16	21	13	3.4	26.2	33	0	0	977
17	22	154	18.3	11.9	0	0	0	2230
18	23	39	8.6	22.1	0	0	0	1547
19	24	150	32.9	21.9	0	0	0	4905
20	594401	614	25.1	4.1	0	0	0	1739
21	02	543	55.6	10.2	0	0	0	2405
22	03	233	17.0	7.3	0	0	0	2258
23	04	625	60.2	9.6	0	0	0	3092
24	05	158	16.9	10.7	0	0	0	625
25	06	522	34.6	6.6	0	0	0	1710
26	07	244	10.9	4.5	0	0	0	636
27	08	350	36.2	10.3	0	0	0	1895
28	09	128	10.3	8.0	0	0	0	677
29	10	150	17.2	11.5	0	0	0	986
30	11	86	2.3	2.7	0	0	0	132
31	12	126	5.9	4.7	0	0	0	444
32	14	769	8.7	1.1	0	0	0	2428
33	15	85	4.7	5.5	0	0	0	282
34	16	445	17.6	4.0	0	0	0	2810
35	40	174	8.0	4.6	0	0	0	7647
36	41	19	4.4	23.2	0	0	0	7457
37	42	270	4.8	1.8	0	0	0	4188
38	43	461	10.1	2.2	0	0	0	6970
39	44	404	20.9	5.2	0	0	0	7934
40	45	820	17.1	2.1	0	0	0	5685
41	46	527	21.4	4.1	0	0	0	4407
42	47	663	13.3	2.0	0	0	0	3132
43	48	693	13.6	2.0	0	0	37	2111
44	49	771	44.5	5.8	0	0	0	15374
45	50	852	—	—	0	0	0	5568
46	51	407	—	—	0	0	0	3769
47	52	328	19.0	5.8	0	0	0	2892
48	53	634	44.4	7.0	0	0	0	9703
49	54	474	13.6	2.9	0	0	0	4138

from the upper 150-m water column in the Bering Sea and northern North Pacific 1968.

per 1000 m³					Wet weight (g/1000 m³)		
S. nagae	*S. minima*	*Eukrohnia hamata*	Unidentified	Total	*Sagitta elegans*	*Eukrohnia hamata*	Other chaetognaths
0	0	500	42	8500	46.5	1.2	0.0
0	0	736	490	6079	10.6	1.2	0.2
0	0	458	542	4542	7.5	0.5	0.0
0	0	4574	426	7403	6.3	4.6	0.1
0	0	1566	482	4056	8.4	1.6	1.2
0	0	530	177	3215	4.3	0.5	0.4
0	0	211	0	562	0.4	0.1	—
38	0	3409	379	4281	0.4	1.6	0.1
0	0	332	0	387	0.4	0.2	0.0
0	0	2092	213	3121	1.0	1.5	0.1
0	0	223	74	669	0.7	0.4	0.2
0	0	3406	87	3842	1.1	1.6	0.1
0	0	254	21	359	0.0	0.2	0.0
136	136	102	646	3163	1.2	0.0	0.9
0	0	96	0	625	4.2	0.0	0.0
0	0	130	293	1433	3.1	0.0	0.3
0	66	66	0	2362	18.1	0.2	0.0
0	55	359	221	2182	8.1	0.2	0.3
0	228	4601	228	9962	24.9	7.7	0.3
0	0	5121	0	6860	10.9	14.2	0.0
0	0	12977	0	15382	30.0	25.6	0.0
0	0	6636	0	8894	2.8	14.2	0.0
0	48	9710	0	12850	31.3	28.9	0.0
0	0	7961	0	8586	5.6	11.3	0.0
0	0	4301	0	6011	24.5	10.1	0.0
0	0	201	0	837	10.7	0.2	0.0
0	0	5323	0	7218	26.0	10.2	0.0
0	0	1258	0	1935	7.4	2.9	0.0
0	0	3380	0	4366	14.9	2.3	0.0
0	0	2881	0	3013	0.2	2.1	0.0
0	0	5259	0	5703	3.1	2.8	0.0
0	0	5217	0	7645	1.3	7.4	0.0
0	0	3041	0	3323	1.8	2.9	0.0
0	0	8905	0	11715	0.9	16.7	0.0
0	0	0	0	7467	8.0	0.0	0.0
0	0	86	0	7543	4.3	0.1	0.0
0	0	2692	0	6880	2.4	2.4	0.0
0	0	1780	0	8750	8.7	1.4	0.0
0	0	7438	83	15455	14.9	6.0	0.0
0	0	4673	89	10447	13.9	3.1	0.1
0	0	9556	111	14074	8.6	12.8	0.0
0	0	6904	36	10072	6.1	7.1	0.1
0	0	4556	74	6778	6.4	7.0	0.2
0	0	14486	0	29860	20.8	23.7	0.0
0	0	9546	0	15114	—	—	—
0	0	12111	0	15880	—	—	—
0	0	4314	0	7206	14.8	4.2	0.0
0	0	990	0	10693	43.5	0.9	0.0
0	0	2716	0	6854	10.0	3.6	0.0

Appendix

No.	No. of station	Wet weight of sample (g/1000 m^3)	Wet weight of chaetognaths (g/1000 m^3)	Percentage of weight of chaetognaths to whole zooplankton (%)	Individuals			
					Sagitta lyra	*S. scrippsae*	*S. maxima*	*S. elegans*
50	594455	41	1.5	3.7	0	0	0	773
51	56	438	11.9	2.7	0	0	0	2414
52	57	201	17.5	8.7	0	0	0	2299
53	58	44	4.2	9.5	0	0	0	221
54	60	82	3.2	3.9	0	0	0	1385
55	61	122	7.9	6.5	0	0	0	2349
56	62	92	35.5	38.6	0	0	0	7667
57	64	148	26.2	17.7	0	0	0	11705
58	65	483	19.5	4.0	0	0	0	5433
59	66	—	5.9	—	0	0	0	792
60	67	376	45.7	12.2	0	0	0	3704
61	604601	507.6	40.3	7.9	0	0	0	1553
62	02	247.3	33.3	13.5	0	0	0	1237
63	03	46.3	6.0	13.0	0	0	0	833
64	04	35.7	10.0	28.0	0	0	0	962
65	05	10.0	10.0	100.0	0	0	0	700
66	07	163.4	38.9	23.8	0	0	0	7665
67	08	269.1	14.0	5.2	0	0	0	1406
68	09	122.4	5.0	4.1	0	0	0	1097
69	10	290.8	18.4	6.3	0	0	0	2305
70	11	540.9	9.9	1.8	0	0	0	4669
71	12	319.4	24.9	7.8	0	0	0	3819
72	13	455.0	22.7	5.0	0	0	0	5400
73	14	594.5	25.2	4.2	0	0	0	7165
74	15	108.5	2.1	1.9	0	0	0	1217
75	16	301.9	6.9	2.3	0	0	0	4178
76	17	209.9	3.1	1.5	0	0	0	2675
77	18	329.4	21.9	6.6	0	0	0	6414
78	19	123.8	0.1	0.1	0	0	0	3861
79	20	205.6	1.1	0.5	0	0	0	4673
80	21	72.5	11.1	15.3	0	0	0	6218
81	22	176.7	8.6	4.9	0	0	0	6466
82	23	227.9	10.4	4.6	0	0	0	6327
83	24	161.8	5.3	3.3	0	0	0	3566
84	25	214.5	24.4	11.4	0	0	0	2215
85	26	254.8	7.6	3.0	0	0	0	6554
86	27	326.9	10.6	3.2	0	0	0	3385
87	28	291.3	10.9	3.7	0	0	0	9130
88	29	210.5	10.5	5.0	0	0	0	7990
89	30	504.2	27.4	5.4	0	0	0	8708
90	31	772.7	2.9	0.4	0	0	0	1727
91	32	172.1	12.8	7.4	0	0	0	4805
92	33	271.3	11.4	4.2	0	0	0	2766
93	34	92.4	30.1	32.6	0	0	0	17059
94	35	226.7	137.1	60.5	0	0	0	37467
95	36	107.1	30.4	28.4	0	0	0	58929
96	37	406.8	151.0	37.1	0	0	0	21356
97	38	107.7	17.2	16.0	0	0	0	104615
98	39	127.7	40.0	31.3	0	0	0	164681

IB. Continued.

per 1000 m³					Wet weight (g/1000 m³)		
S. nagae	*S. minima*	*Eukrohnia hamata*	Unidentified	Total	*Sagitta elegans*	*Eukrohnia hamata*	Other chaetognaths
0	0	273	0	1046	1.4	0.1	0.0
0	0	1576	0	3990	11.2	0.7	0.0
0	0	4138	0	6437	10.2	7.3	0.0
0	0	55	0	276	4.2	0.0	0.0
0	0	1905	0	3290	2.6	0.6	0.0
0	0	1378	0	3725	6.9	1.0	0.0
0	0	2750	0	10417	30.6	4.9	0.0
0	0	3068	0	14773	21.0	5.2	0.0
0	0	2692	0	8125	13.3	6.2	0.0
0	0	542	0	1334	5.3	0.6	0.0
0	0	11217	0	14921	33.9	11.8	0.0
0	0	9886	38	11477	23.6	16.4	0.3
0	0	7634	54	8925	17.4	15.9	0.0
0	0	46	0	879	6.0	0.0	0.0
0	0	110	0	1072	9.9	0.1	0.0
0	0	100	0	800	10.0	0.0	0.0
0	0	3269	272	11206	34.9	3.6	0.4
0	0	0	40	1446	14.0	0.0	0.0
0	0	1097	0	2194	3.8	1.2	0.0
0	0	816	0	3121	18.0	0.4	0.0
0	0	3385	156	8210	7.8	2.0	0.1
0	0	7917	208	11944	15.8	9.0	0.1
0	0	750	250	6400	22.3	0.4	0.0
0	0	3504	276	10945	23.3	1.9	0.0
0	0	1085	185	2487	0.6	1.3	0.2
0	0	1536	270	5984	5.0	1.9	0.0
0	0	41	82	2798	3.1	0.0	0.0
0	0	422	127	6963	21.6	0.3	0.0
0	0	50	0	3911	0.1	0.0	0.0
0	0	561	140	5374	0.9	0.2	0.0
0	0	1036	155	7409	10.4	0.7	0.0
0	0	0	80	6546	8.6	0.0	0.0
0	0	1803	68	8198	8.8	1.5	0.1
0	0	2941	37	6544	2.2	3.1	0.0
0	0	761	0	2976	23.5	0.9	0.0
0	0	837	76	7467	6.7	0.9	0.0
0	0	192	77	3654	10.4	0.2	0.0
0	0	44	130	9304	10.9	0.0	0.0
0	0	287	144	8421	10.5	0.0	0.0
0	0	6500	250	15458	21.5	5.9	0.0
0	0	0	0	1727	2.9	0.0	0.0
0	0	33	195	5033	12.6	0.0	0.2
0	0	0	213	2979	11.0	0.0	0.4
0	0	0	84	17143	30.0	0.0	0.1
0	0	0	0	37467	137.1	0.0	0.0
0	0	0	0	53929	30.4	0.0	0.0
0	0	0	0	21356	151.0	0.0	0.0
0	0	0	0	104615	17.2	0.0	0.0
0	0	0	0	164681	40.0	0.0	0.0

Appendix

No.	No. of station	Wet weight of sample (g/1000 m³)	Wet weight of chaetognaths (g/1000 m³)	Percentage of weight of chaetognaths to whole zooplankton (%)	Individuals			
					Sagitta lyra	*S. scrippsae*	*S. maxima*	*S. elegans*
99	604640	326. 5	50. 6	15. 5	0	0	0	196531
100	41	170. 7	7. 6	4. 5	0	0	0	34878
101	42	333. 3	23. 5	7. 1	0	0	0	15238
102	43	40. 4	5. 4	13. 4	0	0	0	11010
103	44	85. 2	0. 6	0. 7	0	0	0	1250
104	45	21. 0	0. 5	2. 4	0	0	0	2378
105	46	237. 4	3. 4	1. 4	0	0	0	2199
106	47	253. 9	35. 2	13. 9	0	0	0	11347
107	48	395. 0	22. 0	5. 6	0	0	0	7600
108	49	255. 6	20. 4	8. 0	0	0	0	19630
109	50	872. 2	11. 6	1. 3	0	0	0	9586
110	51	4. 7	0. 4	8. 5	0	0	0	1402
111	52	304. 8	11. 3	3. 7	370	0	0	972
112	53	154. 3	15. 6	10. 1	1649	53	0	745
113	54	148. 3	7. 4	5. 0	3156	0	0	38
114	682805	278. 5	12. 0	4. 3	0	0	0	341
115	06	570. 5	15. 0	2. 6	0	0	0	1705
116	07	386. 7	7. 7	2. 0	0	0	0	769
117	10	1032. 7	42. 1	4. 1	0	0	0	2418
118	11	356. 8	6. 7	1. 9	0	0	0	0
119	12	714. 3	2. 6	0. 4	0	0	0	100
120	13	1115. 4	31. 7	2. 8	0	0	0	1232
121	14	1246. 0	14. 0	1. 1	0	0	0	33547
122	15	—	39. 8	—	0	0	0	6560
123	16	1700. 7	118. 6	7. 0	0	0	0	20584
124	17	1380. 8	12. 0	0. 9	0	0	0	3963
125	18	2154. 6	12. 1	0. 6	0	0	0	1959
126	20	1513. 1	6. 0	0. 4	0	0	0	3679
127	21	1538. 3	13. 0	0. 8	0	0	0	2743
128	24	1101. 5	—	—	0	0	0	692
129	25	148. 6	2. 3	1. 5	0	0	0	319
130	28	499. 5	60. 0	12. 0	0	0	0	51852
131	29	—	35. 1	—	0	0	0	10189
132	30	—	62. 0	—	0	0	0	5785
133	32	571. 4	32. 3	5. 7	0	0	0	17302
134	33	216. 4	34. 7	16. 0	0	0	0	6130
135	34	813. 7	72. 6	8. 9	0	0	0	42827
136	35	921. 5	13. 0	1. 4	0	0	0	19468
137	36	260. 6	3. 6	1. 4	0	0	0	391
138	37	2779. 4	96. 7	3. 5	0	0	0	45248
139	39	248. 9	43. 6	17. 5	0	0	0	10714
140	40	—	183. 8	—	0	0	0	11732
141	41	566. 6	140. 7	24. 8	0	0	0	15156
142	50	1183. 8	52. 9	4. 5	0	0	0	18176
143	51	110. 1	0. 3	0. 3	0	0	0	76
144	52	74. 3	0. 0	0. 0	0	0	0	0
145	53	—	1. 1	—	0	0	0	128
146	54	—	1. 1	—	0	0	0	57
147	56	65. 3	0. 9	1. 4	0	0	0	131

IB. Continued.

per 1000 m³					Wet weight (g/1000 m³)		
S. nagae	*S. minima*	*Eukrohnia hamata*	Unidentified	Total	*Sagitta elegans*	*Eukrohnia hamata*	Other chaetognaths
0	0	0	0	196531	50, 0	0, 0	0, 0
0	0	0	0	34878	7, 6	0, 0	0, 0
0	0	0	0	15238	23, 5	0, 0	0, 0
0	0	0	0	11010	5, 4	0, 0	0, 0
0	0	114	0	1364	0, 6	0, 0	0, 0
0	0	70	0	2448	0, 5	0, 0	0, 0
0	0	2121	0	4320	1, 5	1, 9	0, 0
0	0	3990	207	15544	27, 4	7, 6	0, 2
0	0	0	0	7600	22, 0	0, 0	0, 0
0	0	2889	222	22741	17, 3	3, 0	0, 1
0	0	790	263	10639	11, 0	0, 5	0, 1
0	0	187	94	1683	0, 4	0, 0	0, 0
0	0	3565	0	4907	8, 4	2, 9	0, 0
0	0	1330	53	3830	3, 2	1, 5	10, 9
0	0	0	152	3346	0, 0	0, 0	7, 4
0	0	1553	1458	3352	5, 8	2, 4	3, 8
0	0	358	253	2316	13, 3	1, 2	0, 5
0	0	1816	0	2585	6, 0	1, 7	0, 0
0	0	1814	169	4401	38, 0	4, 1	0, 0
0	0	67	1333	1400	0, 0	1, 7	5, 0
0	0	0	0	100	2, 6	0, 0	0, 0
0	0	65	195	1492	23, 8	3, 8	4, 1
0	0	0	426	33973	14, 0	0, 0	0, 0
0	0	0	134	6694	34, 4	0, 0	5, 4
0	0	73	584	21241	118, 5	0, 0	0, 1
0	0	248	62	4273	11, 0	0, 7	0, 3
0	0	1340	103	3402	5, 1	6, 6	0, 4
0	0	416	160	4255	2, 1	2, 8	1, 1
0	0	1600	229	4572	9, 8	1, 9	1, 3
0	0	3599	104	4395	—	10, 7	0, 0
0	0	212	43	574	0, 3	0, 6	1, 4
0	0	2870	3333	58055	56, 6	3, 4	0, 0
0	0	4151	1132	15472	28, 3	4, 2	2, 6
0	0	0	0	5785	62, 0	0, 0	0, 0
0	0	318	0	17620	32, 1	0, 2	0, 0
0	0	240	361	6731	28, 1	0, 5	6, 1
0	0	0	1820	44647	68, 6	4, 0	0, 0
0	0	65	3050	22583	12, 6	0, 1	0, 3
0	0	0	65	456	3, 6	0, 0	0, 0
0	0	0	1780	47028	93, 3	0, 0	3, 4
0	0	0	217	10931	36, 1	0, 0	7, 5
0	0	0	1676	13408	139, 7	0, 0	44, 1
0	0	0	142	15298	140, 1	0, 0	0, 6
0	0	0	3203	21379	49, 6	0, 0	3, 3
0	0	0	0	76	0, 3	0, 0	0, 0
0	0	0	0	0	0, 0	0, 0	0, 0
0	0	0	0	128	1, 1	0, 0	0, 0
0	0	114	0	171	0, 5	0, 6	0, 0
0	0	0	131	262	0, 1	0, 0	0, 8

Appendix

No.	No. of station	Wet weight of sample (g/1000 m³)	Wet weight of chaetognaths (g/1000 m³)	Percentage of weight of chaetognaths to whole zooplankton (%)	Individuals			
					Sagitta lyra	*S. scrippsae*	*S. maxima*	*S. elegans*
148	682857	198. 9	0. 0	0. 0	0	0	0	0
149	58	239. 1	4. 7	2. 0	0	0	0	226
150	59	1078. 9	3. 3	0. 3	0	0	0	153
151	60	187. 5	1. 9	1. 0	0	0	0	1266
152	61	478. 0	67. 2	14. 1	0	0	0	20316
153	62	897. 2	74. 7	8. 3	0	0	0	26589
154	63	554. 7	23. 0	4. 1	0	0	0	9481
155	64	371. 3	87. 3	23. 5	0	0	0	49875
156	67	599. 7	34. 2	5. 7	0	0	0	80510
157	68	365. 1	17. 5	4. 8	0	0	0	30117
158	69	201. 2	33. 9	16. 9	0	0	0	11455
159	70	603. 2	23. 5	3. 9	0	0	0	23492
160	71	269. 1	83. 9	31. 2	0	0	0	29260
161	73	—	0. 0	—	0	0	0	0
162	74	122. 3	12. 1	9. 9	0	0	0	4768
163	75	32. 8	0. 6	1. 8	0	0	0	262
164	76	136. 7	9. 1	6. 7	0	0	0	9875
165	77	306. 0	15. 2	5. 0	0	0	0	5146
166	78	95. 7	4. 0	4. 2	0	0	0	1138
167	79	152. 1	7. 7	5. 1	0	0	0	1119
168	80	527. 7	34. 5	6. 5	0	0	0	15678

Appendix IIA–F. *Full data on chaetognath species collected by simultaneous horizontal tows from 50°N to 35°N on Cruise KH-69-4 of "Hakuhō Maru" in the summer of*

Appendix

No. of station/Position/Date /Time (LZT) /Volume filtered (m³)		KH691/49°53.8′N 154°51.8′W/August		
Estimated depth of collection (m)		0	29	59
Wet weight of sample (g/haul)		387. 9	111. 9	121. 3
(g/1000 m³)		984. 5	284. 0	307. 9
Wet weight of chaetognaths (g/haul)		0. 28	0. 84	0. 19
(g/1000 m³)		0. 7	2. 1	0. 5
Percentage of weight of chaetognaths to whole zooplankton		0. 1	0. 7	0. 2
Individuals per 1000 m³	*Sagitta enflata*	0	0	0
	S. hexaptera	0	0	0
	S. lyra	0	0	0
	S. scrippsae	0	0	0
	S. elegans	893	173	56
	S. nagae	0	0	0
	S. pacifica	0	0	0
	S. neglecta	0	0	0
	S. minima	0	0	0
	S. neodecipiens	0	0	0

IB. Continued.

per 1000 m^3					Wet weight (g/1000 m^3)		
S. nagae	*S. minima*	*Eukrohnia hamata*	Unidentified	Total	*Sagitta elegans*	*Eukrohnia hamata*	Other chaetognaths
0	0	0	0	0	0. 0	0. 0	0. 0
0	0	1065	32	1323	0. 8	1. 8	2. 1
0	0	649	0	802	0. 4	2. 9	0. 0
0	0	44	0	1310	1. 9	0. 0	0. 0
0	0	0	0	20316	67. 2	0. 0	0. 0
0	0	0	888	27477	70. 3	0. 0	4. 4
0	0	0	1574	11055	23. 0	0. 0	0. 0
0	0	0	1407	51282	85. 8	0. 0	1. 5
0	0	0	1349	81859	34. 2	0. 0	0. 0
0	0	0	261	30378	5. 7	0. 0	11. 8
0	0	0	929	12384	19. 8	0. 0	14. 1
0	0	0	0	23492	23. 5	0. 0	0. 0
0	0	0	561	29821	83. 9	0. 0	0. 0
0	0	0	0	0	0. 0	0. 0	0. 0
0	0	0	63	4831	11. 1	0. 0	1. 0
0	0	0	164	426	0. 3	0. 0	0. 3
0	0	0	1291	11166	7. 2	0. 0	1. 9
0	0	93	695	5934	14. 4	0. 0	0. 8
0	0	0	517	1655	1. 1	0. 0	2. 9
0	0	134	313	1566	4. 7	0. 4	2. 6
0	0	1258	844	17775	30. 8	1. 5	3. 2

with 9–10 MTD 56-cm nets from the upper 700 m at 4 stations located on long. 155° W 1969.

IIA.

23–24, 1969/2345–0045/394

88	120	230	350	470	590	700
28. 6	56. 1	39. 4	39. 8	19. 6	2. 5	16. 7
72. 6	142. 4	100. 0	101. 0	49. 7	6. 3	42. 4
0. 50	0. 28	1. 87	2. 11	1. 06	0. 03	0. 25
1. 3	0. 7	4. 7	5. 4	2. 7	0. 1	0. 6
1. 8	0. 5	4. 7	5. 3	5. 4	1. 6	1. 4
0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	0	0	0	0	0
96	20	30	0	6	6	0
0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	0	0	0	0	0

Appendix

No. of station/Position/Date /Time (LZT)/Volume filtered (m^3)		KH691/49°53.8′N 154°51.8′W/August		
Estimated depth of collection (m)		0	29	59
Individuals per 1000 m^3	*Sagitta zetesios*	0	0	0
	S. macrocephala	0	0	0
	Pterosagitta draco	0	0	0
	Eukrohnia hamata	80	16	330
	E. bathypelagica	0	0	0
	Krohnitta subtilis	0	0	0
	Damaged and unidentified	142	0	0
	Total	1115	189	386

Appendix

No. of station/Position/Date /Time (LZT)/Volume filtered (m^3)		KH691/49°58.5′N 155°24.0′W/August		
Estimated depth of collection (m)		0	24	47
Wet weight of sample (g/haul)		12.7	290.0	322.0
(g/1000 m^3)		32.2	736.0	817.3
Wet weight of chaetognaths (g/haul)		0.01	0.52	1.72
(g/1000 m^3)		0.03	1.3	4.4
Percentage of weight of chaetognaths to whole zooplankton		0.1	0.2	0.5
Individuals per 1000 m^3	*Sagitta enflata*	0	0	0
	S. hexaptera	0	0	0
	S. lyra	0	0	0
	S. scrippsae	0	0	0
	S. elegans	487	5706	3096
	S. nagae	0	0	0
	S. pacifica	0	0	0
	S. neglecta	0	0	0
	S. minima	0	0	0
	S. neodecipiens	0	0	0
	S. zetesios	0	0	0
	S. macrocephala	0	0	0
	Pterosagitta draco	0	0	0
	Eukrohnia hamata	0	0	20
	E. bathypelagica	0	0	0
	Krohnitta subtilis	0	0	0
	Damaged and unidentified	0	0	162
	Total	487	5706	3278

IIA. Continued.

23–24, 1969/2345–0045/394

88	120	230	350	470	590	700
0	0	0	0	0	0	0
0	0	0	0	0	0	6
0	0	0	0	0	0	0
1117	1299	7629	3041	822	56	513
0	0	0	16	995	16	244
0	0	0	0	0	0	0
0	0	0	0	0	0	0
1213	1319	7659	3057	1823	78	763

IIB.

25, 1969/0910–1010/394

71	94	190	280	380	470	
64.1	46.5	145.3	167.6	242.7	142.9	
162.7	118.0	368.0	425.4	616.0	362.7	
1.69	1.38	4.04	1.80	1.10	1.36	
4.3	3.5	10.3	4.6	2.8	3.5	
2.6	3.0	2.8	1.1	0.5	1.0	
0	0	0	0	0	0	
0	0	0	0	0	0	
0	0	0	0	0	0	
0	0	0	0	0	20	
3731	350	360	40	80	152	
0	0	0	0	0	0	
0	0	0	0	0	0	
0	0	0	0	0	0	
0	0	0	0	0	0	
0	0	0	0	0	0	
0	0	0	0	0	0	
0	0	0	0	0	0	
0	0	0	0	0	0	
482	4765	9964	4716	8772	5479	
0	0	6	10	160	294	
0	0	0	0	0	0	
66	0	0	0	0	0	
4279	5025	10330	4766	9012	5945	

Appendix

No. of station/Position/Date /Time (LZT)/Volume filtered (m^3)		KH692/45°00.7′N 154°57.2′W/August		
Estimated depth of collection (m)		0	26	53
Wet weight of sample (g/haul)		23.0	39.5	29.4
(g/1000 m^3)		100.0	171.7	127.8
Wet weight of chaetognaths (g/haul)		—	0.05	0.16
(g/1000 m^3)		—	0.2	0.7
Percentage of weight of chaetognaths to whole zooplankton (%)		—	0.1	0.5
Individuals per 1000 m^3	*Sagitta enflata*	0	0	0
	S. hexaptera	0	0	0
	S. lyra	0	0	0
	S. scrippsae	0	0	0
	S. elegans	261	230	9
	S. nagae	0	0	0
	S. pacifica	0	0	0
	S. neglecta	0	0	0
	S. minima	0	0	0
	S. neodecipiens	0	0	0
	S. zetesios	0	0	0
	S. macrocephala	0	0	0
	Pterosagitta draco	0	0	0
	Eukrohnia hamata	0	78	26
	E. bathypelagica	0	0	0
	Krohnitta subtilis	0	0	0
	Damaged and unidentified	548	683	1313
	Total	809	991	1348

Appendix

No. of station/Position/Date /Time (LZT)/Volume filtered (m^3)		KH693/39°53.2′N 154°36.8′W/August		
Estimated depth of collection (m)		0	28	56
Wet weight of sample (g/haul)		33.6	113.0	34.9
(g/1000 m^3)		85.3	286.8	88.6
Wet weight of chaetognaths (g/haul)		0.26	0.00	0.36
(g/1000 m^3)		0.7	0.0	0.9
Percentage of weight of chaetognaths to whole zooplankton (%)		0.8	0.0	1.0
Individuals per 1000 m^3	*Sagitta enflata*	66	0	0
	S. hexaptera	0	0	0
	S. lyra	25	0	10
	S. scrippsae	112	0	1142
	S. elegans	0	0	0
	S. nagae	46	0	0
	S. pacifica	0	0	0
	S. neglecta	0	0	0

IIC.

[29, 1969/1515–1550/230

79	110	210	320	420	530	
29.4	—	7.3	14.5	10.9	12.7	
127.8	—	31.7	63.0	47.4	55.2	
0.20	—	0.22	0.09	0.14	0.16	
0.9	—	1.0	0.4	0.6	0.7	
0.7	—	3.2	0.6	1.3	1.3	
0	—	0	0	0	0	
0	—	0	0	0	0	
0	—	0	0	0	0	
0	—	0	0	0	0	
78	—	78	34	70	17	
0	—	0	0	0	0	
0	—	0	0	0	0	
0	—	0	0	0	0	
0	—	0	0	0	0	
0	—	0	0	0	0	
0	—	0	0	0	0	
0	—	0	0	0	0	
0	—	0	0	0	0	
43	—	791	1340	1243	517	
0	—	0	0	0	4	
0	—	0	0	0	0	
1209	—	391	156	87	57	
1330	—	1260	1530	1400	595	

IID.

31-September 1, 1969/2315–0015/394

84	110	220	340	450	560	
35.5	14.5	5.3	5.5	21.5	15.0	
90.1	36.8	13.5	14.0	54.6	38.1	
1.40	0.02	0.02	0.03	0.38	0.44	
3.6	0.1	0.1	0.1	1.0	1.1	
4.0	0.3	0.7	0.7	1.8	2.9	
0	—	0	0	0	0	
0	—	0	0	0	0	
10	—	0	10	0	0	
922	—	20	20	234	142	
0	—	0	0	5	0	
0	—	0	0	5	0	
0	—	0	0	0	0	
0	—	0	0	0	0	

Appendix

No. of station/Position, Date /Time (LZT)/Volume filtered (m)		KH693/39°53.2′N 154°36.8′W/August		
Estimated depth of collection (m)		0	28	56
Individuals per 1000 m³	*Sagitta minima*	3411	0	0
	S. neodecipiens	0	0	0
	S. zetesios	0	0	0
	S. macrocephala	0	0	0
	Pterosagitta draco	0	0	0
	Eukrohnia hamata	0	0	30
	E. bathypelagica	0	0	0
	Krohnitta subtilis	5	0	0
	Damaged and unidentified	279	0	569
	Total	3944	0	1751

Appendix

No. of station/Position/Date /Time (LZT)/Volume filtered (m³)		KH693/40°00.1′N 154°29.4′W/September		
Estimated depth of collection (m)		0	29	58
Wet weight of sample (g/haul)		12.5	77.6	118.0
(g/1000 m³)		31.7	797.0	299.5
Wet weight of chaetognaths (g/haul)		0.02	0.02	0.00
(g/1000 m³)		0.1	0.1	0.0
Percentage of weight of chaetognaths to whole zooplankton (%)		0.3	0.1	0.0
Individuals per 1000 m³	*Sagitta enflata*	0	0	0
	S. hexaptera	0	0	0
	S. lyra	0	0	0
	S. scrippsae	0	91	0
	S. elegans	0	0	0
	S. nagae	0	0	0
	S. pacifica	0	0	0
	S. neglecta	0	0	0
	S. minima	1457	122	0
	S. neodecipiens	0	0	0
	S. zetesios	0	0	0
	S. macrocephala	0	0	0
	Pterosagitta draco	0	0	0
	Eukrohnia hamata	0	0	0
	E. bathypelagica	0	0	0
	Krohnitta subtilis	5	0	0
	Damaged and unidentified	234	46	0
	Total	1696	259	0

IID. Continued.

31-September 1, 1969/2315–0015/394

84	110	220	340	450	560
0	—	5	5	0	0
0	—	102	107	0	0
0	—	0	0	0	0
0	—	0	0	0	0
0	—	0	0	0	0
16	—	0	41	66	20
0	—	0	0	15	0
0	—	5	0	10	0
342	—	117	86	264	178
1290	706	249	269	599	340

IIE.

1, 1969/0853–0953/394

88	120	230	350	470	580
19.0	15.5	7.1	20.4	20.1	18.3
48.2	39.6	18.0	51.8	51.0	46.4
0.82	0.62	0.06	0.10	0.10	0.17
2.1	1.6	0.2	0.3	0.3	0.4
4.4	4.0	1.1	0.6	0.6	0.9
0	0	0	0	0	0
15	5	0	0	0	0
56	66	5	0	0	0
2751	1147	41	157	117	173
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0
3391	670	1792	1046	0	20
0	0	0	0	0	0
0	0	0	0	0	15
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	56	25	127
0	0	0	0	0	0
0	0	0	66	0	0
426	91	15	279	132	56
6639	1979	1853	1604	274	391

Appendix IIF.

No. of station/Position/Date /Time (LZT)/Volume filtered (m³)		KH694/35°01.0′N 154°51.5′W/September 6, 1969/1543–1643/ 394
Estimated depth of collection (m)		0
Wet weight of sample (g/haul)		19.4
(g/1000 m³)		49.2
Wet weight of chaetognaths (g/haul)		1.33
(g/1000 m³)		3.4
Percentage of weight of chaetognaths to whole zooplankton (%)		6.9
Individuals per 1000 m³	*Sagitta enflata*	0
	S. hexaptera	0
	S. lyra	0
	S. scrippsae	0
	S. elegans	0
	S. nagae	0
	S. pacifica	10056
	S. neglecta	15
	S. minima	0
	S. neodecipiens	0
	S. zetesios	0
	S. macrocephala	0
	Pterosagitta draco	76
	Eukrohnia hamata	0
	E. bathypelagica	0
	Krohnitta subtilis	0
	Damaged and unidentified	107
	Total	10254

Appendix III. *Full data on the measurements of* Sagitta

Animal No.	Body length (mm)	Tail length (mm)	Percentage of tail length to body length (%)	Length of ventral ganglion (mm)	Percentage of length of ventral ganglion to body length (%)	Number of hooks
L18	1.225	Absent	—	0.376	30.69	Absent
L20	1.295	Absent	—	0.298	23.01	Absent
L22	1.356	Absent	—	0.333	24.56	Absent
L13	1.374	Absent	—	0.455	33.11	Absent
L 9	1.383	Absent	—	0.420	30.37	Absent
L 6	1.42	Absent	—	0.45	31.69	Absent
L17	1.444	Absent	—	0.403	27.91	Absent
L25	1.470	0.665	45.24	0.315	21.43	Absent
L 8	1.479	0.665	44.96	0.411	27.79	Absent
L21	1.505	0.665	44.19	0.368	24.45	Absent
L23	1.505	0.569	37.81	0.298	19.80	Absent
L24	1.514	0.683	45.11	0.324	21.40	Absent

elegans *from newly-hatched larvae to adult forms.*

Anterior fin	Eye pigments	Length of collarette (mm)	Percentage of length of collarette to body length (%)	Ovary length (mm)	Percentage of ovary length to body length (%)	Height of seminal vesicle (mm)
Absent	Absent	—	—	Absent	—	Absent
Absent	Absent	—	—	Absent	—	Absent
Absent	Absent	—	—	Absent	—	Absent
Absent	Absent	1. 015	73. 87	Absent	—	Absent
Absent	Absent	1. 050	75. 92	Absent	—	Absent
Absent	Absent	1. 02	71. 83	Absent	—	Absent
Absent	Absent	—	—	Absent	—	Absent
Absent	Absent	—	—	Absent	—	Absent
Absent	Absent	1. 199	81. 07	Absent	—	Absent
Absent	Absent	—	—	Absent	—	Absent
Absent	Absent	—	—	Absent	—	Absent
Absent	Absent	—	—	Absent	—	Absent

Appendix

Animal No.	Body length (mm)	Tail length (mm)	Percentage of tail length to body length (%)	Length of ventral ganglion (mm)	Percentage of length of ventral ganglion to body length (%)	Number of hooks
L10	1.523	0.665	43.66	0.464	30.47	Absent
L12	1.523	0.61	40.05	0.455	29.88	Absent
L 2	1.540	0.679	44.09	0.376	24.42	Absent
L15	1.575	0.665	42.22	0.385	24.44	Absent
L 1	1.584	0.700	44.19	0.525	33.14	Absent
L 4	1.601	0.648	40.47	0.403	25.17	Absent
L19	1.619	0.726	44.84	0.403	24.89	Absent
L11	1.645	0.700	42.55	0.376	22.86	Absent
L 7	1.69	0.68	40.24	0.32	18.93	8
L14	1.759	0.735	41.79	0.411	23.37	—
L 3	1.873	0.770	41.11	0.403	21.52	—
L26	1.94	0.86	44.33	—	—	8
L 5	2.20	0.95	43.18	0.48	21.82	—
F 1	2.045	0.900	44.01	—	—	—
F 2	2.095	0.950	45.35	—	—	—
F 4	2.508	0.84	33.49	—	—	8
F 3	3.010	1.005	33.39	—	—	—
F 8	3.16	0.95	30.06	0.50	15.82	—
F 7	3.35	1.00	29.85	0.40	11.94	—
F 6	3.41	1.02	29.91	0.45	13.20	7
F 5	3.75	1.10	29.33	0.52	13.87	—
F17	4.00	1.10	27.50	0.55	13.75	—
F10	4.16	1.12	26.92	0.58	13.94	—
F12	4.55	1.10	24.18	0.64	14.07	7
F 9	4.60	1.14	24.78	0.64	13.91	—
F18	4.66	1.19	25.54	0.60	12.88	7
F14	4.72	1.15	24.36	0.60	12.71	7
F11	4.75	1.20	25.26	0.60	12.63	—
F19	4.79	1.19	24.84	0.64	13.36	—
F15	4.80	1.20	25.00	0.60	12.50	7
F13	4.85	1.25	25.77	0.64	13.20	8
F16	4.94	1.32	26.72	0.65	13.16	—
F25	5.10	1.25	24.51	0.60	11.76	—
F20	5.20	1.30	25.00	0.70	13.46	7
F29	5.20	1.25	24.04	0.72	13.85	—
F28	5.41	1.26	23.29	0.57	10.54	—
F24	5.50	1.25	22.73	0.60	10.91	7
F26	5.70	1.33	23.33	0.75	13.16	—
F21	5.75	1.25	21.74	0.70	12.17	8
F22	5.82	1.30	22.34	0.75	12.89	8
F42	6.05	1.30	21.49	0.64	10.58	8
F38	6.05	1.35	22.31	0.65	10.74	8
F27	6.10	1.40	22.95	0.54	8.85	—
F23	6.15	1.40	22.76	0.70	11.38	7

III. Continued.

Anterior fin	Eye pigments	Length of collarette (mm)	Percentage of length of collarette to body length (%)	Ovary length (mm)	Percentage of ovary length to body length (%)	Height of seminal vesicle (mm)
Absent	Absent	1.190	78.14	Absent	—	Absent
Absent	Absent	1.138	74.72	Absent	—	Absent
Absent	Absent	1.155	75.00	Absent	—	Absent
Absent	Absent	1.103	70.03	Absent	—	Absent
Absent	Absent	1.208	76.26	Absent	—	Absent
Absent	Absent	1.225	76.51	Absent	—	Absent
Absent	Absent	—	—	Absent	—	Absent
Absent	Absent	1.225	74.47	Absent	—	Absent
Absent	Absent	1.20	71.01	Absent	—	Absent
Absent	Absent	1.313	74.64	Absent	—	Absent
Absent	Absent	1.418	75.71	Absent	—	Absent
Absent	Absent	—	—	Absent	—	Absent
Absent	Absent	1.42	64.55	Absent	—	Absent
Absent	Present	—	—	Absent	—	Absent
Absent	Present	—	—	Absent	—	Absent
Absent	Present	—	—	Absent	—	Absent
Absent	Present	—	—	Absent	—	Absent
Absent	Present	—	—	Absent	—	Absent
Absent	Present	—	—	Absent	—	Absent
Absent	Present	—	—	Absent	—	Absent
Absent	Present	—	—	Absent	—	Absent
Absent	Present	—	—	Absent	—	Absent
Absent	Present	—	—	Absent	—	Absent
Absent	Present	—	—	Absent	—	Absent
Absent	Present	—	—	Absent	—	Absent
Absent	Present	—	—	Absent	—	Absent
Absent	Present	—	—	Absent	—	Absent
Absent	Present	—	—	Absent	—	Absent
Absent	Present	—	—	Absent	—	Absent
Absent	Present	—	—	Absent	—	Absent
Absent	Present	—	—	Absent	—	Absent
Absent	Present	—	—	Absent	—	Absent
Present	Present	—	—	Absent	—	Absent
Absent	Present	—	—	Absent	—	Absent
Present	Present	—	—	Absent	—	Absent
—	Present	—	—	Absent	—	Absent
Absent	Present	—	—	Absent	—	Absent
—	Present	—	—	Absent	—	Absent
Present	Present	—	—	Absent	—	Absent
Present	Present	—	—	Absent	—	Absent
Absent	Present	—	—	Absent	—	Absent
Absent	Present	—	—	Absent	—	Absent
Present	Present	—	—	Absent	—	Absent
Present	Present	—	—	Absent	—	Absent

Appendix

Animal No.	Body length (mm)	Tail length (mm)	Percentage of tail length to body length (%)	Length of ventral ganglion (mm)	Percentage of length of ventral ganglion to body length (%)	Number of hooks
F41	6.30	1.45	23.02	0.75	11.90	7
F30	6.31	1.40	22.19	0.75	11.89	—
F43	6.35	1.45	22.83	0.72	11.34	7
F35	6.40	1.32	20.63	0.75	11.72	7
F32	6.45	1.45	22.48	0.65	10.08	7
F40	6.50	1.63	25.08	0.65	10.00	—
F33	6.83	1.30	19.03	0.75	10.98	7
F34	6.85	1.50	21.90	0.75	10.95	—
F31	6.95	1.50	21.58	0.70	10.07	8
F37	7.10	1.30	18.31	0.70	9.86	8
F45	7.64	1.51	19.76	0.85	11.13	8
F46	7.75	1.45	18.71	0.80	10.32	—
F36	7.85	1.50	19.11	0.75	9.55	7
F39	7.91	1.45	18.33	0.81	10.24	7
F44	7.91	1.60	20.23	0.80	10.11	7
F48	7.95	1.55	19.50	0.80	10.06	—
F47	8.00	1.55	19.38	0.80	10.00	—
F49	8.15	1.65	20.25	0.75	9.20	7
F52	8.25	1.75	21.21	0.83	10.06	—
F51	8.45	1.62	19.17	0.85	10.06	7
F50	8.80	1.70	19.32	0.80	9.09	7
F53	9.35	1.75	18.72	0.85	9.09	—
F55	10.10	1.60	15.84	0.80	7.92	—
F56	10.36	1.92	18.64	0.80	7.77	7
F54	10.50	1.80	17.14	0.82	7.81	8
F58	11.25	2.10	18.67	0.80	7.11	7
F57	11.95	2.38	19.92	0.95	7.95	—
F60	12.10	2.28	18.84	0.95	7.85	—
F59	12.70	2.36	18.58	0.84	6.61	—
F61	12.85	2.43	18.91	0.90	7.00	—
F62	13.75	2.40	17.45	0.90	6.55	8
F63	13.75	2.36	17.16	0.90	6.55	—
F64	14.65	2.65	18.09	1.00	6.83	—
F66	15.85	2.80	17.67	0.85	5.36	8
F67	16.75	3.00	17.91	0.87	5.19	—
F69	17.07	3.07	17.98	0.95	5.55	8
F68	18.15	3.00	16.53	0.95	5.23	8
F71	18.20	3.20	17.58	1.10	6.04	7
F70	18.73	3.25	17.35	1.10	5.87	8
F72	19.40	3.35	17.27	1.05	5.41	8
F74	20.40	3.60	17.65	1.05	5.15	—
F73	21.55	3.80	17.63	1.10	5.10	8
F75	22.55	3.90	17.29	1.10	4.88	8
F77	22.95	4.01	17.47	1.25	5.45	12
F78	23.09	4.02	17.41	1.10	4.76	11

III. Continued.

Anterior fin	Eye pigments	Length of collarette (mm)	Percentage of length of collarette to body length (%)	Ovary length (mm)	Percentage of ovary length to body length (%)	Height of seminal vesicle (mm)
Present	Present	—	—	Absent	—	Absent
Present	Present	—	—	Absent	—	Absent
Present	Present	—	—	Absent	—	Absent
Present	Present	—	—	Absent	—	Absent
Absent	Present	—	—	Absent	—	Absent
Present	Present	—	—	Absent	—	Absent
Present	Present	—	—	Absent	—	Absent
Present	Present	—	—	Absent	—	Absent
Present	Present	—	—	Absent	—	Absent
Present	Present	—	—	Absent	—	Absent
Present	Present	—	—	Absent	—	Absent
Present	Present	—	—	Absent	—	Absent
Present	Present	—	—	Absent	—	Absent
Present	Present	—	—	Absent	—	Absent
Present	Present	—	—	0.24	3.03	Absent
Present	Present	—	—	0.27	3.40	Absent
Present	Present	—	—	0.28	3.50	Absent
Present	Present	—	—	0.30	3.68	Absent
Present	Present	—	—	0.22	2.67	Absent
Present	Present	—	—	0.35	4.14	Absent
Present	Present	—	—	0.30	3.41	Absent
Present	Present	—	—	0.48	5.13	Absent
Present	Present	—	—	0.51	5.05	Absent
Present	Present	—	—	0.44	4.27	Absent
Present	Present	—	—	0.45	4.29	Absent
Present	Present	—	—	0.46	4.09	Absent
Present	Present	—	—	0.53	4.44	Absent
Present	Present	—	—	0.47	3.88	Absent
Present	Present	—	—	0.51	4.02	Absent
Present	Present	—	—	0.65	5.06	Absent
Present	Present	—	—	0.63	4.58	Absent
Present	Present	—	—	0.65	4.73	Absent
Present	Present	—	—	0.85	5.80	Absent
Present	Present	—	—	1.05	6.62	Absent
Present	Present	—	—	0.85	5.07	Absent
Present	Present	—	—	1.00	5.86	Absent
Present	Present	—	—	1.45	7.99	Absent
Present	Present	—	—	1.30	7.14	Present
Present	Present	—	—	1.50	8.01	Present
Present	Present	—	—	1.60	8.25	0.05
Present	Present	—	—	1.02	5.00	0.10
Present	Present	—	—	1.82	8.45	0.05
Present	Present	—	—	4.65	20.62	0.12
Present	Present	—	—	2.55	11.11	0.13
Present	Present	—	—	3.43	14.85	0.15

Appendix

Animal No.	Body length (mm)	Tail length (mm)	Percentage of tail length to body length (%)	Length of ventral ganglion (mm)	Percentage of length of ventral ganglion to body length (%)	Number of hooks
F76	23.90	4.10	17.15	1.10	4.60	8
F79	24.05	4.35	18.09	1.25	5.20	11
F80	24.98	4.40	17.61	1.15	4.60	11
F81	25.58	4.31	16.85	1.25	4.89	11
F82	27.15	4.90	18.05	1.25	4.60	12
F83	27.66	4.80	17.35	1.25	4.52	11

Appendix IV. *Biomass of zooplankton other than chaetognaths in the eastern Bering Sea in the summer of 1968.*

No. of station	Maximum depth of collection (m)	Standing stock of zooplankton other than chaetognaths		
		(g wet wt/1000 m^3)	(mg C/m^3)	(mg C/m^2)
682812	139	711.7	42.7	5935.3
14	90	1232.0	73.9	6651.0
15	68	—	—	—
30	40	—	—	—
34	83	741.1	44.5	3693.5
36	110	257.0	15.4	1694.0
37	87	2682.7	161.0	14007.0
39	65	205.3	12.3	799.5
40	45	—	—	—
41	52	425.9	25.6	1331.2
50	82	1130.9	67.9	5567.8
61	103	410.8	24.6	2533.8
62	83	822.5	49.3	4091.9
63	75	531.7	31.9	2392.5
64	67	284.0	17.0	1139.0
67	44	565.5	33.9	1491.6
68	35	347.6	20.9	731.5
69	30	167.3	10.0	300.0
70	44	579.7	34.8	1531.2
71	50	185.2	11.1	555.0
74	106	110.2	6.6	699.6
75	96	32.2	1.9	182.4
76	84	127.6	7.7	646.8
78	92	91.7	5.5	506.0

III. Continued.

Anterior fin	Eye pigments	Length of collarette (mm)	Percentage of length of collarette to body length (%)	Ovary length (mm)	Percentage of ovary length to body length (%)	Height of seminal vesicle (mm)
Present	Present	—	—	4.85	20.29	0.14
Present	Present	—	—	3.80	15.80	0.15
Present	Present	—	—	2.55	10.21	0.10
Present	Present	—	—	6.35	24.82	0.15
Present	Present	—	—	3.20	11.79	0.15
Present	Present	—	—	1.80	6.51	0.14