THE CHAETOGNATHS OF WESTERN CANADIAN COASTAL WATERS

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ABSTRACT

A study of the chaetognath population in the waters of western Canada was undertaken to discover what species were present and to determine their distribution. The plankton samples examined were collected by the Institute of Oceanography of the University of British Columbia in the summers of 1953 and 1954 from eleven representative areas along the entire coastline of western Canada. It was hoped that the distribution study would correlate with fundamental oceanographic data, and that the presence or absence of a given species of chaetognath might prove to be an indicator of oceanographic conditions. Four species of chaetognaths, representing two genera, were found to be present. One species, Sagitta elegans, was the most abundant and widely distributed species, occurring at least in small numbers in all the areas sampled. It was characteristic of the mixed coastal waters over the continental shelf and of the inland waters. Eukrohnia hamata, an oceanic form, occurred in most regions in small numbers as an immigrant, and was abundant toward the edge of the continental shelf. Sagitta lyra, strictly a deep sea species, was found only in the open waters along the outer coasts, and a few specimens of Sagitta decipiens, another oceanic form, were also taken in deep hauls from areas exposed to open ocean influence. It was found that the outer limit of Sagitta elegans corresponded with the inner limits of all three oceanic forms, though Eukrohnia hamata invaded the inland waters to some extent.

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1. INTRODUCTION

Chaetognaths, or arrow worms, are conspicuous members of the plankton communities of the oceans of the world. Moreover in some localities they have been found to be important indicator organisms, certain species being confined to waters with characteristic properties. When the requirements of various species are known, it may be possible to predict the character and origin of a water mass on the basis of the presence therein of a particular species of chaetognath. In the English Channel, for example, where two species are predominant, the abundance of either one of the species gives information concerning the source of that particular water, and this knowledge is of value to the herring industry (Kemp,1938).

While chaetognaths have been and are being studied extensively in other parts of the world, including the east coast of Canada (Huntsman,1919), very little is known about the species present off the west coast of Canada or about their distribution. Except for the work of Michael (1909-1919) in the San Diego region of California, there are no other published studies of chaetognaths for any area in the eastern Pacific. Therefore, the present study was undertaken to acquire information about the chaetognath fauna of the coastal waters of Canada's western province of British Columbia, and with the hope, also, that the distribution study would correlate with fundamental oceanographic data, and perhaps form a basis for more extensive plankton studies.

2. HISTORY

Chaetognaths were first discovered in 1775 by Martin Slabber, who classified them as worms, and gave the species the generic name of *Sagitta*. The arrow worm was not mentioned again until 1827, when Quoy and Gaimard rediscovered it in the Mediterranean and published a description under the name of *Sagitta bipunctata*. They also called it in French "Fleche deux points," or arrow with two dots, both names referring to the shape and to the two black spots which they thought might be the eyes. The description was very inadequate, since the animals are transparent and the microscope used was not as good as the modern instruments. Present day interest in the arrow worms dates from the publication of Quoy and Gaimard, but the confusion as to which species of arrow worm was *Sagitta bipunctata* was not cleared up for many years.

Leuchart (1854) created the Order Chaetognatha (Gr. *chaite*, bristle; *gnathos*, jaw). Two genera were recognized at that time, one *Sagitta* (Slabber) and the other *Spadella* (Langerhans). In 1883 Grassi produced a general work on the whole group, but probably the most important taxonomic contributions were made in 1911 by Ritter-Zahony, whose careful and complete descriptions and good drawings have been the basis for all work on identification since that time. Also important were the contemporary works of Michael (1909, 1911) for the San Diego region. Thomson (1947) in Australia has brought up to date all the information on classification, technique, synonymy, and distribution, and produced an excellent key for all valid species besides compiling an extensive bibliography. According to Thomson, there are now ten genera of chaetognaths, including one fossil form. Seven of these genera are monospecific, in one genus there are two species, in another three, and the genus Sagitta contains twenty-six valid species. Several forms that have been described are still considered doubtful species, and further investigation will be required, especially as to the environmental influence on the characteristics used for classification.

3. ZOOGEOGRAPHICAL DISTRIBUTION

While chaetognaths occur in all oceans, the individual species are restricted to different regions, some being deep sea forms, others living in the epiplankton of the open sea, and some inhabiting only the mixed waters over the continental shelves near land. None of the species is completely cosmopolitan, though many have a very wide distribution. Thomson (1947) states that eight of the Indo-Pacific forms do not reach the Atlantic, while five Atlantic species have not been reported from the Indo-Pacific. Species of deep oceanic waters have a wider distribution than those dwelling near the surface, since they are subject to very little temperature change, though in the warmer parts of the world they are found at greater depths than they are in the colder regions. Also the immature stages are often nearer the surface, while the mature ones are in deeper water. Thomson says that the bulk of the chaetognath population, as with the plankton in general, is concentrated in the upper one-hundred meters. Some of the species live at much greater depths, however, and according to Ritter-Záhony (1911b) they have been taken at depths of over 1200 meters. It is possible that some species could be found in deeper hauls than are ordinarily made. Fraser (1949) states that one specimen of Krohnitta subtalis (Grassi) was taken where the depth exceeded 1800 meters.

In a regional study, one must be aware of the fact that the chaetognath population may vary with the season, from one year to another, or with shifts in the currents. Some intensive regional studies have been undertaken, but much of the information available at present has been obtained through examination of material collected on occasional expeditions. As more regions are thoroughly studied, it will be possible to form a much better picture of the global distribution of the chaetognaths.

4. OCEANOGRAPHIC FACTORS INFLUENCING OCCURRENCE IN BRITISH COLUMBIA

In the north Pacific Ocean, the chaetognath fauna has been investigated in the Philippines (Michael,1919), in Japan (Tokioka,1940), and in southern California off San Diego (Michael,1909,1911). It might be expected that species found in any of these regions could also occur in the British Columbia waters.

The North Equatorial Current flowing past the Philippines becomes the Kuroshio Current along the south and east of Japan. Here it is joined by cold waters from the north and continues eastward across the Pacific, approaching the coast of America in the vicinity of Vancouver Island. About four hundred miles offshore it divides, part turning north and the remainder south (Tully,1953). It closely approaches the shore in the region of the northern Queen Charlotte Islands and Dixon Entrance.

Some of the waters of the Japanese Current pass along the coast of British Columbia as the southerly flowing Alaskan Current. This current follows a serpentine path to and from shore, according to Tully (1937).

The coastal counter current carrying the fresh waters drained from the land, especially by the rivers large and small, tends to flow northward along the coast from San Diego to the Aleutian Islands of Alaska. Off the west coast of Vancouver Island, this current flows northwestward regardless of the ebb and flow of the tidal currents, though part of it is dissipated in the gyros of the Alaskan current. The counter currents are strongest in May and June, when the spring freshets of the big rivers reach the sea. At this time the counter currents are ten or more miles wide and carrying a layer of brackish waters at the surface, but later in the season they recede as the river flow decreases (Tully,1953). A marginal turbulence between the coastal and the Alaskan currents is present, and zones of sinking and rising waters occur throughout the area

(Tully,1937).

The distribution of the fish in the waters of British Columbia is known. Sub-arctic, sub-tropic, and temperate species are found in various areas at all times of the year, or are seasonal or occasional visitors (Clemens and Wilby,1946). The oceanic isotherm of the sub-tropical zone, which is opposite San Francisco, curves northward and reaches the shores of the Queen Charlotte Islands and farther north. Sub-arctic temperatures occur north of that to the Aleutian Islands. Off shore at the surface of the ocean, where the water is warmer, the southern forms of fish are found. The northern species occur in deep water, or may appear in the upwelled cold water near shore.

In view of the facts just presented as to oceanic currents, temperatures, and the known distribution of fish, it was expected that there would be a varied chaetognath fauna along the western Canadian coast. Fifteen species have been identified from the Philippines, eighteen from Japan, and thirteen from San Diego. However, four species only, representing two genera, were collected from the areas sampled in Canada. One additional species has been identified from the region (Sagitta planctonis) by Dr. J.M. Thomson of Australia for Mr. R. Le Brasseur, student of the University of British Columbia. The specimen may have been an isolated immigrant, since it was not found in the present survey, either in the region from which it had been reported or from any other. Since no stations were located in the deep waters off the coast or beyond the continental shelf, future work in the deep ocean could reveal the presence of many more species.

The species found at any time in the British Columbia waters and their presence or absence in the other three regions of the north Pacific ocean, where the chaetognath fauna has been investigated, are shown in the following table:

In order of Abundance	PHILIPPINES (Michael,1919)	JAPAN (Tokioka,1940)	CALIFORNIA (Michael,1911)
Sagitta elegans	-	+	-
Eukrohnia hamata	+	-	+
Sagitta lyra	-	+	+
Sagitta decipiens	+	+	-
Sagitta planctonis	+	-	+

The distribution is of interest, though there is insufficient information about the life histories of the different species and their occurrence in intervening areas to draw significant conclusions.

5. AFFINITIES OF THE CHAETOGNATHS

The position of arrow worms in the Animal Kingdom is uncertain. The Phylum Chaetognatha is usually grouped with miscellaneous other small phyla and the issue avoided. In the

Zoological Record chaetognaths are found under "Vermes." Burfield (1927) says that they have been classified variously as Coelenterata, Nemathelminthes, Arthropoda, Mollusca, Vertebrata, Enteropneusta, and Annelida, but suggests that the chaetognaths probably originated from a very ancient, free-swimming stock, having a coelom still communicating with the gut, and called Protocoelomata by some writers. According to this theory, all coelomate animals have descended from that hypothetical stock, and the Chaetognatha would be considered as a very ancient and not greatly modified offshoot. Walcott (1911) found adult chaetognaths in British Columbia Middle Cambrian shales which were very much like the young animals of the present day just emerged from the egg, since there was no tail septum and the intestine terminated a little beyond the center of the tail.

Meek, discussing the classification in 1928, mentions the same long list of phyla to which the arrow worms had at some time been assigned, adding Echinodermata, Rotifera, and Brachiopoda. He says that it has long been known that developmentally the Chaetognatha come closely into relationship with the Echinodermata and the Enteropneusta. The structural features of the adult, however, have been a puzzle and have lead to the confusion in classification. Meek thinks that chaetognaths are almost vertebrate in their organization, and that the Echinodermata, Enteropneusta, and Pterobranchia present such an assemblage of similar characters, sharing besides such a peculiarity of development, that he proposes the combination of all four groups into a new phylum, called Hydrocoela.

6. ANATOMY OF CHAETOGNATHS

Arrow worms are slender, transparent animals, the largest of which may reach a length of over seven centimeters. The body is divided by transverse septa into head, trunk, and tail regions. Delicate fins along the sides are used for balance and buoyancy rather than for swimming, and there is also a caudal fin at the end of the tail. On the head are lateral hooks and two paired rows of teeth used for seizing prey and crambing it into the ventral mouth. A hood, originating in the neck region, partly covers the hooks. The eyes usually appear as two dark spots on the dorsal surface of the head. On the trunk a prominent structure is the swollen ventral ganglion located on the ventral surface toward the anterior end. Just anterior to the tail septum is the anal opening, and the surrounding tissues may be quite enlarged and protruding. In the larger specimens, spots consisting of groups of sensory fibers may be seen scattered regularly over the surface of the body and the fins.

Since the animals are transparent, the internal organs may also be seen. The intestine is a straight tube leading from the mouth to the anus, the part in the head often being called the pharynx. Mature or maturing specimens have ovaries extending forward from the tail septum and seminal vesicles projecting laterally at the sides of the tail. Chaetognaths usually have longitudinal muscles only, and they swim in short, vibrating spurts.

In the illustration, (Plate I), the most obvious external and internal structures, which include those necessary for species identification, are drawn and labeled.

Very small chaetognaths just emerged from the egg look like adults, though the proportions are different. The tail is longer, and the ventral ganglion, which does not increase much in size as the animal grows in length, is almost as long as the trunk. Meek (1928) presents an excellent diagram of the relative rates of growth of the various parts of the body of Sagitta elegans. The animals lengthen considerably before they start to mature, though the length at maturity is greatly influenced by the temperature of the water. Individuals of a given species mature earlier in warmer water, and in cold water often grow to a comparatively large size before maturing.

Chaetognaths are hermaphroditic and protandric. A description of the maturity stages of Sagitta elegans, as observed during this study, will serve to illustrate fairly well the development of chaetognaths in general. The male reproductive organs are located in the tail, and eventually the entire tail becomes completely filled with sperms. Even before the slightest trace of ovaries can be seen, the tail may be so full of spermatocytes and sperms as to be opaque and yellow in color. The seminal vesicles then begin to push out at the sides of the tail. At this time, short, rod-like ovaries make their appearance. The seminal vesicles grow rapidly and the sperms are ex-

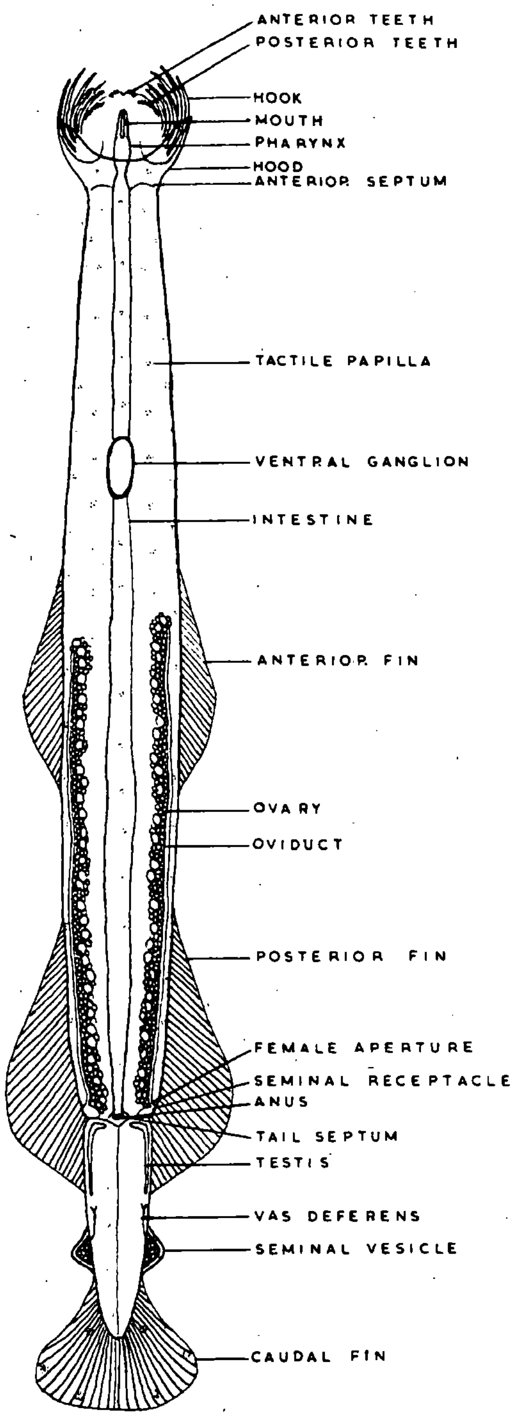


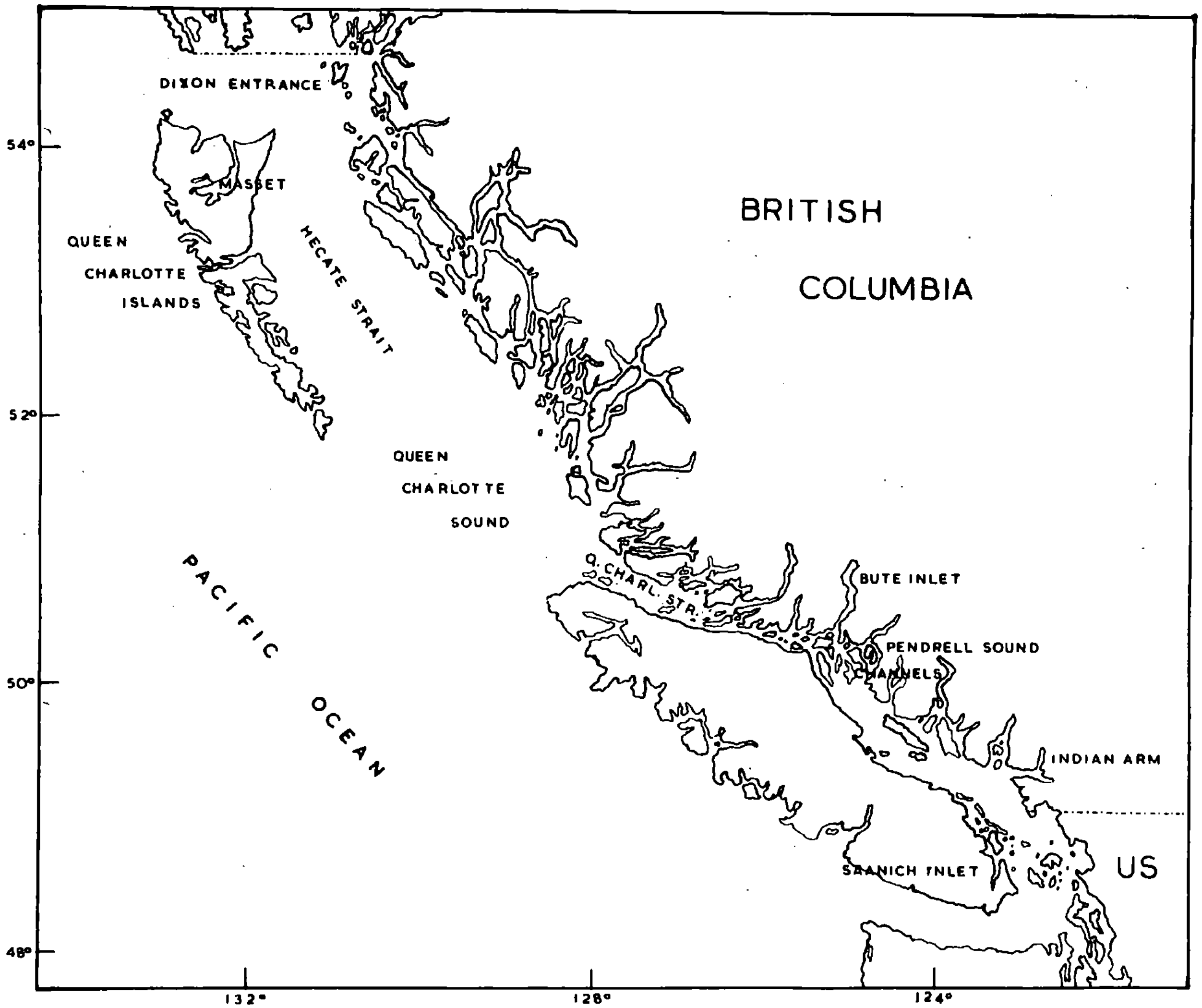
PLATE I. SAGITTA, DIAGRAMMATIC DRAWING - VENTRAL VIEW truded by the time the ovaries are completely mature. The tail is then left empty and transparent, and the spent seminal vesicles are empty and ragged-looking. The shape of the seminal vesicles and their location on the tail in relation to the lateral and tail fins are of specific importance, and when present they are an excellent recognition characteristic.

As the ovaries mature they elongate, the length to which they reach anteriorly varying with age and species. In the early stages they appear slender and rod-like, the eggs all being small and of the same size. As some of the eggs increase in size, the ovaries become broader and bunchy in appearance. In mature individuals the ovaries have reached their extreme length and all the eggs are large. Animals that are about spent have a few large eggs scattered along the length of the ovaries with empty spaces between. Extrusion of the eggs appears to complete the life cycle for almost all species of chaetognaths, though Sagitta enflata, according to Thomson (1947) is thought to have two cycles of reproduction. Of Sagitta elegans, Meek (1928) says, "It is evident that, after spawning as females, Sagitta disappears, or apparently disappears, and it may be therefore that the end of maturity is also the end event of life." In discussing this aspect of the chaetognath life history, Meek stated that two generations of S.elegans seem to develop each year in the Northumbrian waters, one spawning in the Spring and the other in the Autumn. On the other hand, Russell (1933) says that "Sagitta is an animal which passes through several generations in the year, possibly five or six according to the species." In the cold polar waters of the Canadian eastern Arctic with temperatures of $1^{o}C$ or below, Dunbar (1941) found that the arctic sub-species of _Sagitta elegans_ takes two years to reach maturity.

Reading of _Sagitta_ by Burfield (1927) is indispensable for a complete study of the anatomy and development of chaetognaths. The subject of the Memoir is _Sagitta bipunctata_.

7. MATERIAL

The collections studied in this investigation were made by Dr. Robert F. Scagel, assistant professor of oceanography, during cruises of the C.G.M.V.Cancolim II in 1953 and of the C.N.A.V.Ehkoli in 1954. Almost all of the material was collected from June 12 to September 5 in 1953, but one region was visited and hauls made on May 21 and 22 in 1954. The stations were located in a variety of areas extending from the northernmost to the southernmost part of the Pacific coast of Canada, as indicated on the map, Map I, and a study of the hauls gives a fairly accurate overall picture of the distribution of the chaetognath population at that time, with the exception that there were no stations along the west coast of Vancouver Island nor in the deep waters of the Pacific Ocean. Since the cruises were not planned for the purpose of this investigation, and plankton hauls were not made at every station occupied, it is fortunate that the stations at which hauls were made were so well placed for a population and distribution study of the



MAP I. COAST OF WESTERN CANADA – REGIONS INVESTIGATED entire region. The material available for study included 139 hauls from 113 stations. Several hauls were made at some of the stations where the ship was anchored for extensive oceanographic surveys.

The hauls were made with a #10 nylon net having a diameter of thirty inches, the net being drawn vertically from the bottom to the surface. At every station data were recorded for temperatures, salinities, and oxygen content at various levels. Since these data are indispensable in a distribution study, as much use as possible was made of the information. However, when specimens are taken in vertical hauls, there is no way of knowing at what depth the chaetognaths were taken and what oceanographic conditions actually prevailed at that particular level.

The samples were preserved in 4% formalin, which has been found to be the best preservative for chaetognaths, and most of the specimens were in very good condition.

An unsuccessful attempt was made to keep specimens alive in the laboratory for a study of their development and activity, besides a more accurate examination of their anatomy. The chaetognaths were collected during two winter cruises made by the Institute of Oceanography of the University of British Columbia. The animals were put immediately into ten-liter jugs. The first specimens collected were not aerated, but a second collection was made in which aerators, taken on the cruise for the purpose, were put into use as soon as the specimens were taken. Upon arrival at the laboratory the jars were immersed in previously prepared water baths at 7°C, an average winter water temperature in the locality in which the specimens were taken. However in both cases the arrow worms were dead the next day. Burfield (1927) also found that he was unable to keep specimens alive for more than twenty-four hours, though he was able to use running sea water.

8. TECHNIQUE OF EXAMINATION

Chaetognaths do not require staining for examination. If the specimens have been well preserved, they can be examined most easily by floating them in a little of the 4% formalin in which they have been preserved.

Because of their size, preliminary examination with a binocular microscope is satisfactory. Evenually, when the species have become easily recognizable, the use of the binocular microscope is all that is necessary. Any specimen that looks different can then be examined more closely under a compound microscope.

For examination of the animals, some type of container is required that will hold enough fluid to cover the specimens, but keep them from floating around too much, and be flat enough to be used with a compound microscope. Rectangular cells built up on two sizes of slides with waterproof plastic glue met the requirements. On a large two by three inch slide the cell was 1 3/4" long by 1 1/4" wide. This was long enough for all specimens found and wide enough to hold a row of ten or more chaetognaths at the same time for rapid examination with the binocular microscope. On a standard-sized slide the cell was 1 1/2" by 5/8". This size was useful for viewing one to a few specimens at a time with the compound microscope. The cell was enough smaller than the large one to prevent the animal's floating out of view. These two cell-slides were indispensable during the entire course of the work.

To remove the animals from the plankton sample, it was found that the best method was to pour a relatively thin layer of the sample into a petri dish. Under the petri dish was a square of black paper. Most of the larger animals could be seen without lifting the dish, but some were seen more easily if the dish was picked up and rocked slowly. The binocular microscope was often used for the final examination, though not always. Any chaetognaths that were caught in the net used could be seen with the naked eye, the very smallest being almost two millimeters long.

As the animals were picked out of the sample, they were put into another petri dish containing the 4% formalin. In this the copepods, other animals, and plants that had stuck to them were washed off. The chaetognaths were then transferred a few at a time from this dish to the slide with the large cell for examination under the binocular microscope. All handling was done with a pair of curved forceps. The animals were picked up just posterior of the neck region to avoid injury to the fins. Measuring was done with a thin, flat, transparent ruler. This was easily slipped under the slide.

For more thorough examination of the fins, or in order to see and count the teeth and hooks, the animals were usually transferred to the small cell-slide. It takes a great deal of patience to become adjusted to seeing the teeth. It was found that special lighting and adjustment of the microscope was required before they could be seen well enough to count. The technique employed involved the use of hollow-cone illumination. Various light filters were tried, but green proved to be the most effective. Polarized light was a distinct aid in some cases, and a phase retardation plate helped to differentiate structures. The special lighting technique was developed by Dr. Kenneth Graham, professor of forest entomology, of the University of British Columbia, to whom the writer is greatly indebted. The details in regard to increasing image contrast by the use of hollow-cone illumination are described by Mathews (1953).

To determine the number of specimens present in each sample, the entire sample was examined and all specimens were removed. These were counted and the numbers of mature, maturing, and immature individuals were recorded as shown in the tables. The sizes of the largest and smallest specimens of each were also recorded. Individuals of *Sagitta elegans* were classified as mature if they had well developed ovaries and seminal vesicles; maturing if they had rod-like ovaries and also had seminal vesicles; and immature if there were no seminal vesicles, even though in some cases very small ovaries could be seen. Individuals of the other three species were designated as maturing if they had ovaries but no seminal vesicles, and immature if they had no ovaries.

9. SPECIES IN BRITISH COLUMBIA

Four species only, representing two genera, were found to occur in the areas studied. These species are:

Sagitta elegans Verrill (1873)

Sagitta lyra Krohn (1853)

Sagitta decipiens Fowler (1905)

Eukrohnia hamata (Möbius, 1875)

Two of these species, Sagitta elegans and Eukrohnia hamata, were common, while the other two were found in small numbers only in the open ocean waters of the Queen Charlotte Islands and in Queen Charlotte Sound. It is not difficult to differentiate the species, but S.elegans presents some problems, since it varies from region to region sufficiently in transparency, proportions, and in numbers of hooks and teeth to justify the recognition of three sub-species.

In the descriptions of the species which follow, to facilitate the identification of the local species whether young or mature, observed pecularities and characteristics are included that are helpful, but would not be encountered in the keys or in more formal descriptions.

Eukrohnia hamata (Plate II)

This species, not as abundant as S.elegans, but apt to be present in small numbers in most regions of British Columbia, can not be confused with any other. Even in a dish full of chaetognaths, it appears different to the naked eye. Specimens bent almost at right angles in the region of the ventral ganglion frequently prove to be this species. The bending may possibly be due to localized muscular disintegration following the animal's entrance into water of low salinity, as the species is an oceanic form. Ritter-Zahony (1911a) remarked that some individuals of E.hamata he observed were uncommonly transparent and appeared to be undergoing a slow muscular atrophy. Besides the bending, there is often marked curvature of the entire body. Also, the animals are ragged-looking along the sides, and debris in the form of copepods, other animals, or algae is frequently entangled in the lateral or tail fins or in the hooks. Under the binocular microscope, E.hamata is conspicuous because of the large oil droplets in the intestines. In addition the hooks are usually spread, and there is a distinct neck, making the head appear broad. The fins, wide, delicate, and sparsely rayed, one pair to each side, extend from in front of the ventral ganglion to half way down the tail. The tail has an angular appearance, while other species have smoothly tapering tails. If the animal appears to have no eyes, one can be almost sure that the specimen is E.hamata, since individuals living in cold water have no pigment in their eyes (Thomson,1947), and none of those found in British Columbia waters did have pigment. Examination under the compound microscope reveals conspicuously serrated hooks in young individuals. Also while most chaetognaths, including all the others

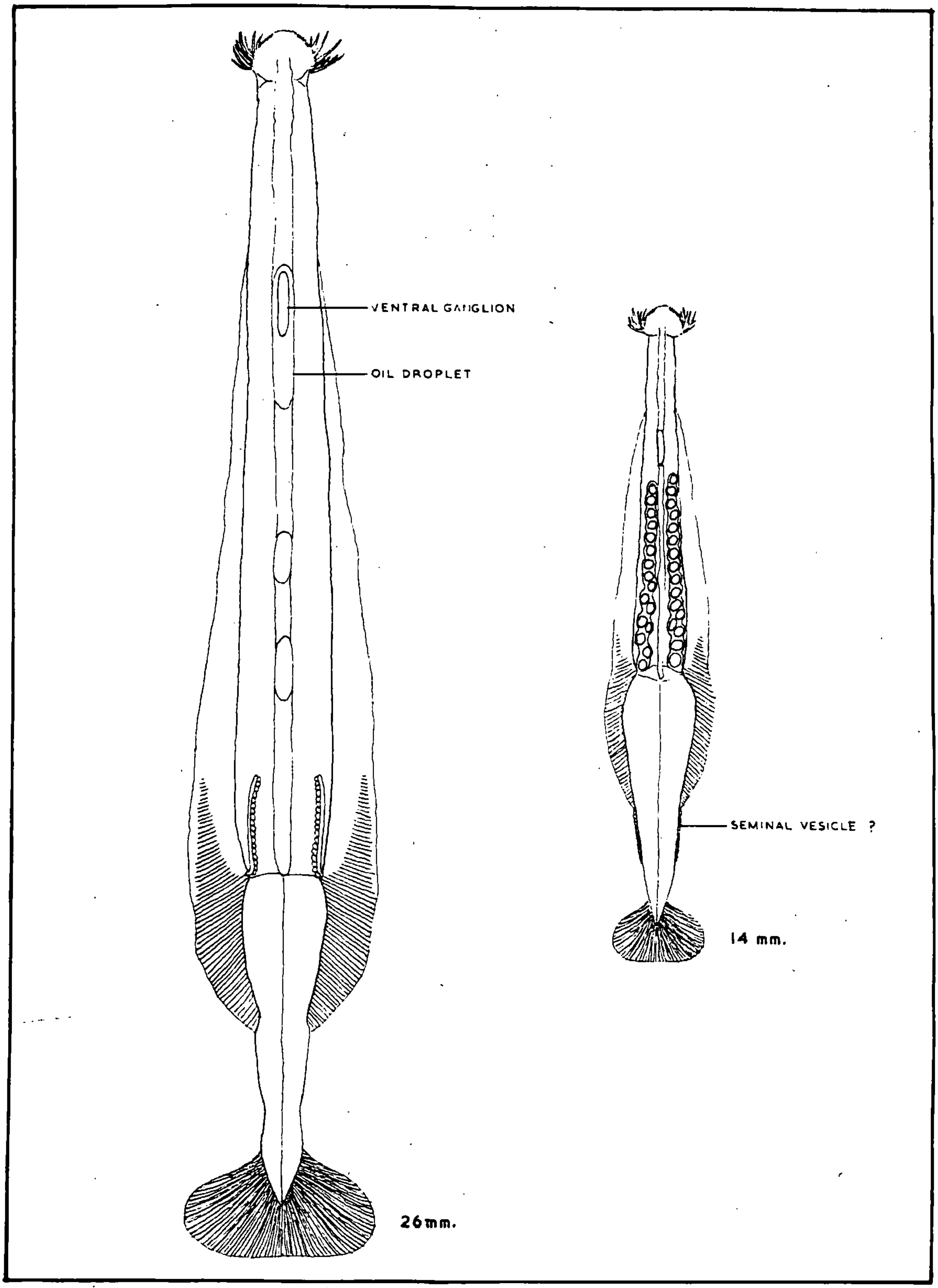


PLATE II. EUKROHNIA HAMATA, LARGE MATURING AND SMALL MATURE - DORSAL VIEWS found in British Columbia, have two paired rows of teeth, Eukrohnia has only one paired row.

Out of the 1018 individuals of E.hamata taken in the entire survey, 1002 were immature, 15 had rod-like or short ovaries, and only one was fully mature. The completely matured specimen had a peculiar appearance, with the trunk almost entirely filled with large eggs, and the tail swollen to about twice the size of the trunk. The drawing, Plate II, shows a large maturing specimen with three conspicuous oil droplets and the much smaller mature individual mentioned above.

Though, as previously stated, E.hamata is an oceanic form, unlike the other deep sea species, it had found its way into the shallow waters of many of the inland passages and inlets of British Columbia. According to Ritter-Zahony (1911b), in the tropics this species occurs at depths of from 400-1000 meters, but in the north it may be found near the surface as well as in the deep waters.

Sagitta elegans (Plate III)

This is the most abundant and widely distributed species in the region. S.elegans, unlike E.hamata, has two pairs of fins along the sides. The posterior ones are relatively long, broad, firm, and oval-shaped, with a greater proportion on the trunk than on the tail. The anterior fins are some distance back from the ventral ganglion and are shorter and narrower than the posterior ones. Both pairs are completely rayed. Sometimes on preservation the sides of the trunk fold in, and the anterior fins are folded out of sight. If the fins can not be seen, they will be exposed by flattening the body gently in the fin region.

The neck of S.elegans is broad, and the head usually does not look any wider than the body. However, should the animal be killed in the act of eating, the head will appear very wide, and the hooks may even be inserted into the mouth. Very relaxed specimens may have the hooks spread.

S.elegans is usually quite stiff and sometimes opaque, but most specimens taken in British Columbia were transparent and many were flabby. The species usually has ten hooks, but though the number varies from eight to thirteen, there are never less than eight. The only other species in the region with which it could be confused, S.decipiens, never has more than seven. The teeth are difficult to see and count, especially in the more opaque specimens, but there are two paired rows of them, and they increase in number as the animals grow longer.

Mature individuals have prominent, conical, seminal vesicles on each side of the tail, either touching the tail fin or very close to it, and distant from the posterior fins. The eggs are large and the ovaries extend well forward into the body cavity. The younger but maturing specimens have flatter seminal vesicles and slender rod-like ovaries, very short and inconspicuous in the youngest animals, but elongated and plainly visible in those approaching maturity.

Sagitta elegans varies sufficiently from one region to another to have made it necessary to divide the species into three sub-species. The sub-species, as designated by Ritter-Zahony, (1911c), are S.elegans elegans, S.elegans arctica, and S.elegans baltica. Both Ritter-Zahony and more recently Huntsman (1919), who investigated the sub-specific differences thoroughly for the species in eastern Canadian waters, agree as to the general characteristics separating them. The figures used for length of body and tail proportions in the following descriptions are Dr. Huntsman's.

S.elegans baltica is the smallest of the three forms, the largest caught in eastern Canada measuring 26 millimeters. The tail is shortest in proportion, ranging from 14-19% of the entire body, 16% being the usual proportion. This sub-species has slightly fewer hooks; eight in the smaller specimens, increasing to ten in longer ones, and decreasing to eight again in the longest. The maximum number of teeth attained is also lower than in the other sub-species. The Baltic form is more flabby, limp, and transparent than the others; the anterior fins are somewhat smaller; and the ovaries are shorter, reaching no farther than the anterior end of the posterior fins.

S.elegans arctica grows to the largest size, the longest specimen obtained by Dr. Huntsman measuring 52 millimeters. The tail is long in proportion, ranging from 19-22%, with 20% being most frequent. A greater number of hooks develop, the number increasing from eight to twelve as the animals lengthen, and there is no decrease in the longest specimens as in the Baltic form. The number of teeth also increases as the animals grow longer, more being present eventually than in the two other sub-species. The arctic form is more opaque and stiff than the others, and the ovaries extend farther forward in the trunk.

S.elegans elegans is the intermediate form, the maximum length being 36 millimeters in eastern Canada. The tail varies from 16-20%, usually being 17% of the body. The hooks increase from eight to eleven and, as in the arctic form, there is no decrease as the animals grow longer. The number of teeth and variations in the fins, length of ovaries, and transparency is also intermediate.

Dr. Huntsman says that the differences between the three sub-species are caused by differences in temperature during development. He found that the tail percentages did not vary much in the young individuals of the three kinds and concluded that this was due to the fact that the young of all occurred near the surface, where the water was relatively warm and the temperature did not vary much from one region to another. However, the older individuals occupy the deep water, which does vary in temperature from place to place, and in these older animals differences in tail percentages appear. Ritter-Zahony (1911b) attributes the differences between the sub-species to the variation in the salinity of the water.

In the early stages of the work in identification of the species in the western Canadian waters, there was some delay caused by the fact that Michael had confused S.elegans with some other species in his identification in 1911 (Plate 2,

p. 173) and in his key in 1919, in which he located the seminal vesicles adjacent to the posterior fins rather than adjacent to the tail fin. Later, after this difficulty was cleared up, the sub-specific differences seemed great enough at times to cause some doubt as to the species observed. Consequently Dr. J.M. Thomson, senior research officer of the Commonwealth Scientific and Industrial Research Organization, Division of Fisheries, in Australia was requested to identify specimens from Canadian waters. This he kindly consented to do, and sixteen unlabeled specimens, including thirteen S.elegans of all sizes, proportions, stages of maturity, and differences in transparency were sent to him. Specimens of S.lyra and S.decipiens were included. His identifications confirmed the conclusions reached by this investigator, and cleared up all doubt as to the identification of S.elegans in all its forms.

In the distribution survey of the species in the western Canadian waters, no attempt was made to differentiate between the sub-species. Neither did Dr. Huntsman find it worth while to consider them separately in his work in eastern Canada, since he found the sub-species were not distinct but were connected by intermediates. Fraser (1937) also observed that there is very little clear-cut difference between the varieties of S.elegans, and that a complete sequence of types can be found.

In the entire survey, 9564 specimens of S.elegans were taken. Of this 654 were mature, 473 maturing, and 8437 were immature. There were almost ten times as many S.elegans as

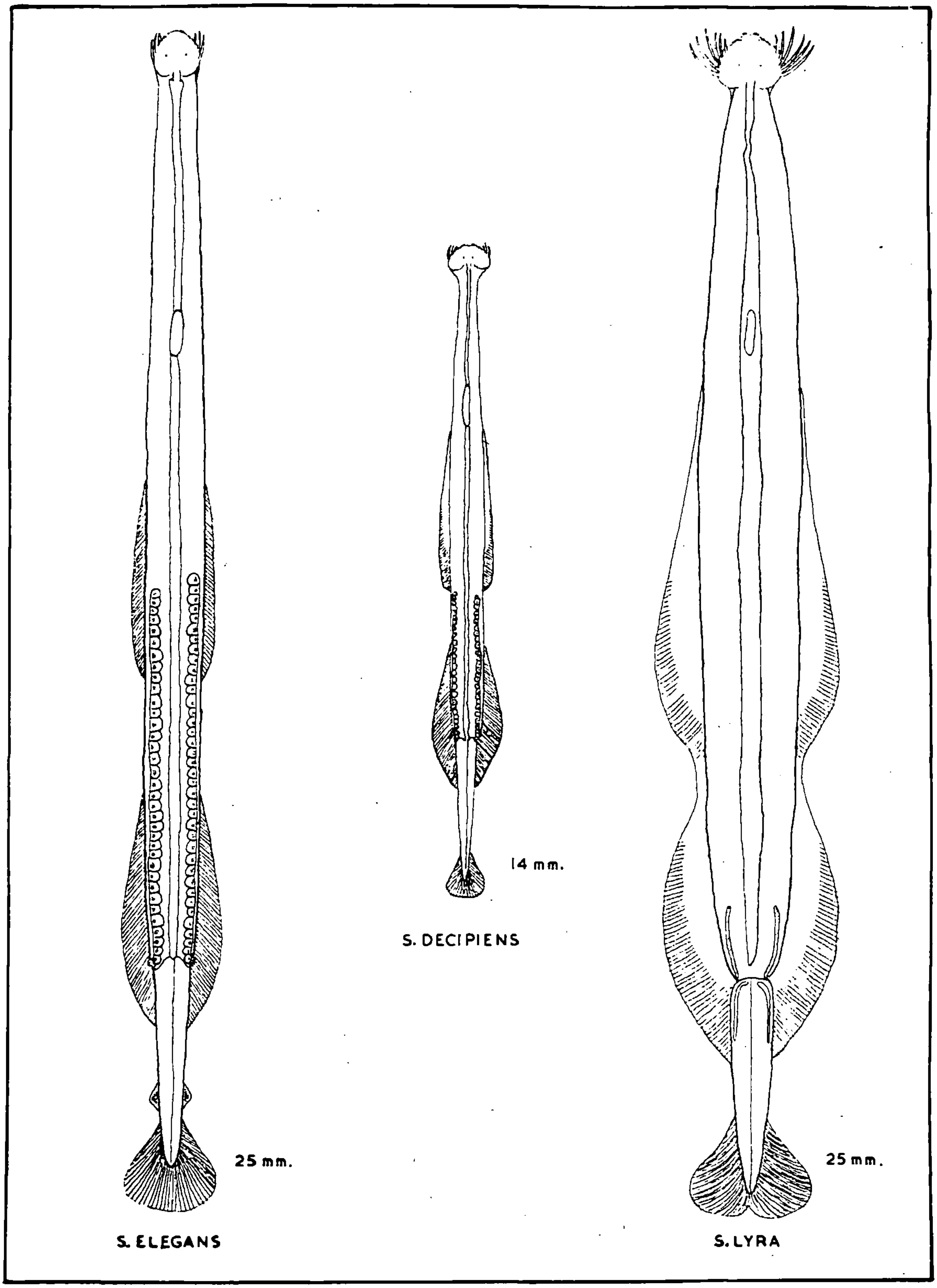


PLATE III. SAGITTA ELEGANS, S. DECIPIENS, AND S. LYRA - DORSAL VIEWS there were E.hamata, which was second in abundance. In addition, 12% of the specimens of S.elegans were mature or maturing, compared with 2% for E.hamata.

S.elegans has now been definitely established as the dominant species of chaetognath on both sides of the northern Atlantic and Pacific oceans, living in the cold, less saline waters of the continental shelves. In eastern Canada, Dr. Huntsmans calls it "the characteristic Sagitta of our Atlantic waters," because of its general occurrence in the shallow water all along the coast. Very few specimens were collected by him in the deep waters beyond the continental shelf. Tokioka (1940) states that S.elegans is common in the cold waters of north-east Tyosen in Japan. Ritter-Zahony (1911b) found that it inhabited the northern European coasts, and Meek (1928) found that it was most often the dominant species in the Northumbrian plankton, while Fraser (1937) stated that it was dominant where Atlantic water mixes with the coastal waters of western and northern Scotland. The species does not occur in the southern hemisphere.

Sagitta lyra (Plate III)

This species is strikingly different from either E.hamata or S.elegans. The body is flabby and exceedingly transparent. The entire trunk appears wide, constricting abruptly at the neck and also at the tail septum. The head is broad and, in contrast to the transparency of the body, is opaque, while the tail is noticeably slender and very transparent. The two pairs of lateral fins are delicate and sparsely rayed, the anterior ones being longer than the posterior. Because the fins are joined together, they appear almost like the single lateral fins of E.hamata,however they do not extend as far forward, reaching just short of the ventral ganglion, rather than extending anterior of it. The caudal fins appear both delicate and unusually large. The rich-brown-colored hooks are conspicuous in comparison with the tan ones of the other species. The location of the anal opening is distinctive in S.lyra. In most species, including the others found in British Columbia, the opening is adjacent to the tail septum, but in S.lyra it is very definitely anterior of the tail septum. The teeth of S.lyra are also characteristic. They are often very few in number, and the anterior ones are long and projecting upwards. The western Canadian specimens had only two to four anterior teeth and two to seven posterior ones in each row, but the number is variable, and large specimens may have as many as eight anterior teeth on each side and up to twelve in the posterior rows.

Of the six specimens taken, only two were maturing and had very slender rod-like ovaries. The longest one, twenty-eight millimeters, had seminal vesicles just starting to develop. Mature specimens have small, conical ones lying half way between the posterior and tail fins (Ritter-Zahony, 1911a, Illus.). In the transparent tail, unlike S.elegans with its opaque tail, the male reproductive organs are plainly visible. This species grows to a very large size, and while animals over forty to fifty millimeters are seldom captured, Ritter-Zahony (1911a) gives seventy-one millimeters as the maximum size for S.gazellae, which is now considered the cold water form of S.lyra.

S.lyra is an almost cosmopolitan oceanic form usually found at a depth of 300-1000 meters, according to Ritter-Zahony (1911b). He found the young ones in the epiplankton and the mature ones deeper in the mesoplankton. The specimens obtained in the British Columbia region were taken along the west coast of the Queen Charlotte Islands, none occurring in any of the inland waters.

Sagitta decipiens (Plate III)

This species resembles S.elegans somewhat. The body is stiff and transparent and the fins delicate. The lateral fins are separated as in S.elegans, but the anterior ones are longer than the posterior and reach almost to the ventral ganglion. The caudal fin is small, and the tail is proportionately longer than it is in the other two species of Sagitta in the region. In those taken the tail was 25% of the total body length, but the possible range generally given is 20-31%. Fowler (1905), in his original description, gives 25-40%. Compared with the usual 16-20% for S.elegans and 16% for S.lyra, 25% is noticeable. The head is usually definitely wider than the body, rather rectangular in shape, and also quite transparent. The hooks are slender, scarcely pigmented, and few in number, varying from five to seven. Specimens with five, six, and seven were observed. S.elegans does not have less than eight. The eyes of S.decipiens are characteristic and different from those of other chaetognaths (Ritter-Zahony, 1911a, Illus.). They are longer than wide, looking like two joined slender beads. The species is a small one, seldom reaching fifteen millimeters. Though Ritter-Zahony (1911c) stated that it attained a size of twenty millimeters, Thomson (1947) gives twelve to thirteen millimeters for mature specimens in Australia. The largest taken in British Columbia was fourteen millimeters long and not fully mature.

Four excellent specimens of S.decipiens were taken, as well as three others damaged beyond certain identification. The four that were definitely S.decipiens had well developed ovaries, the longest reaching to the posterior end of the anterior fins, but none had seminal vesicles. The tails were clear, and though one contained quite a number of transparent sperms, the tail was not opaque, as in S.elegans at the same stage of maturity. Neither were the tails as transparent as those of S.lyra, since the internal male reproductive organs were not visible. Ritter-Zahony (1911a) and Michael (1919) have pictured the seminal vesicles of S.decipiens as comma shaped, widest at the anterior end, and adjacent to the tail fin.

S.decipiens, like E.hamata and S.lyra, is an oceanic form, which according to Ritter-Zahony (1911b) is found between 200 and 1200 meters. As with S.lyra, the mature forms are also found at the greater depths. The British Columbia specimens were taken in two deep hauls of 249 and 366 meters in open ocean areas.

It is not suggested that all species of chaetognaths which occur in British Columbia waters have been obtained. In the present investigation, S.decipiens is reported for the first time, and S.planctonis was not taken. Other species undoubtedly occur in the deep oceanic waters and could be collected in offshore hauls. Also some of these might be carried into coastal waters from time to time.

The following keys were constructed for the identification of specimens collected during this investigation. It is intended that the use of the keys, with the aid of the descriptions, will enable one to identify the species most commonly found in the area. Any specimen that could not be identified would possibly represent a new record. Because so few species are involved, difficult structural characteristics, such as the numbers of teeth, and structure and articulation of parts of the hooks, can be avoided in the keys. The first key is for use with well preserved individuals with all fins present, the characteristics being obvious enough for identification under a binocular microscope only. In the other key, no use of the fins is made, but examination with a compound microscope, and perhaps some manipulation, is necessary for counting the hooks.

KEYS TO THE SPECIES OF BRITISH COLUMBIA CHAETOGNATHS

FOR WELL-PRESERVED SPECIMENS

1. One pair of lateral fins or two connected pairs

    2. No pigment in the eyes; anal opening at tail septum; oil droplets in the intestine . . . E. hamata

    2. Eyes pigmented; anal opening anterior of tail septum; no oil droplets in the intestine. . S. lyra

1. Two pairs of lateral fins widely separated

    2. Anterior fins longer than posterior and almost reaching ventral ganglion; hooks 5-7, usually 6 . . . . S. decipiens

    2. Anterior fins shorter than posterior and some distance behind ventral ganglion; hooks 8-13, usually 10 . . . . S. elegans

FOR SPECIMENS WITH DAMAGED FINS

1. Anal opening anterior of tail septum . . . . S. lyra

2. Anal opening at tail septum

    2. No pigment in eyes . . . . E. hamata

    2. Eyes pigmented

        3. Hooks 5-7 . . . . S. decipiens

        3. Hooks 8-13 . . . . S. elegans

* * *

10. DISTRIBUTION AND FREQUENCY OF OCCURRENCE

The stations studied in the British Columbia survey were located in eleven representative areas, as indicated on the map (Map I), extending along the entire coast of Canada, from Saanich Inlet in the south to Dixon Entrance in the north. The coastline is characterized by its ruggedness, steep shores, scarcity of beaches, and many deep and long inlets and channels. Numerous rivers of glacial origin discharge large enough volumes of fresh water into the sea to have a marked effect upon the fauna and flora of the region. The distribution of the chaetognaths reflects both the geographic and oceanographic character of the area.

Following is the distribution of chaetognaths by areas.

Area	No. Sta.	No. Hauls	S.elegans	E.hamata	S.lyra	S.decipiens
Saanich Inlet	19	19	1456	23		
Indian Arm	7(4)	12	837			
Pendrell Sound	3	3	55			
Chan. North Str.of Georgia	3	3	204	1		
Bute Inlet	8	26	594	17		
Queen Charlotte Strait	19	19	498	8		
Queen Charlotte Sound	2	2	342	58		3
Hecate Strait	9	10	9	1		
Dixon Entrance	19	19	2656	836		1+3? 4
Masset Sd.& In.	4	4	1847			
W. Queen Charl. Islands	20	22	1066	74	6	

The areas covered in the survey are listed in order from south to north, and the number of stations occupied and number of hauls made are indicated, besides the total numbers of each species of chaetognath taken in the region.

It is obvious that S.elegans, the characteristic species of mixed coastal waters, occurred in abundance in most areas, and was present at least in small numbers in every region sampled.

The oceanic E.hamata was most abundant in localities connected with the open ocean, though a few individuals had invaded most of the inland passages and inlets. No specimens were taken in the three inlets, Indian Arm, Pendrell Sound, and Masset Sound and Inlet. The mouths of Indian Arm and Masset Sound are blocked by shallow, warm, water, and the warm temperature and lack of circulation in Pendrell Sound are a barrier to other plankton animals as well as to chaetognaths. As mentioned previously, few specimens of E.hamata were maturing. Also, no very young ones were taken from the inland waters, and it appears that, on the whole in most localities, those present may have been migrants carried there by the currents. Redfield and Beale (1940) found the same situation in the Gulf of Maine, where E.hamata also ranked second in abundance to S.elegans. They concluded that because E.hamata lives near the surface of the ocean, it comes into the Gulf with the currents, where as a terminal migrant from other regions in which it breeds endemically, it lives as long as circumstances permit and dies without leaving progeny.

S.lyra, another species of the deep sea, is rarely taken near shore. The six specimens obtained were all found off the west coast of the Queen Charlotte Islands very near the edge of the continental shelf. In eastern Canada, Dr. Huntsman found its inner limit was sixty miles off the continental shelf in May and June, but that it was near the edge of the shelf in July and August. The British Columbia specimens were taken in August within a mile or two of the continental shelf. However, there are no data as yet in western Canada for the occurrence of this species during other parts of the year.

A less common oceanic form is S.decipiens. The two regions where it was taken are open coast areas, and both of the hauls were deep, being 249 meters in Queen Charlotte Sound and 366 meters at the outer end of Dixon Entrance. At least four specimens were taken, and in addition three damaged portions of chaetognaths appeared to be S.decipiens also. E.hamata was unusually abundant at the stations where S.decipiens was found, and it appears that the inner limits of S.decipiens overlap somewhat with the outer limits of S.elegans and the region of increasing abundance of E.hamata.

11. DISTRIBUTION IN EACH AREA

The eleven areas sampled are discussed separately, starting with the southernmost and working northward to the region most approaching oceanic conditions off the west coast of the Queen Charlotte Islands. Maps showing the locations of the stations in each area, besides tables giving detailed data for the hauls are included. Evident peculiarities in the distribution of the animals are pointed out, and oceanographic factors possibly influencing the distribution are suggested. Fortunately each area is quite different in geography and water conditions, a fact which adds to the value of the survey.

I SAANICH INLET

Map II; Table 1

Saanich Inlet, near the southeastern tip of Vancouver Island, is an inlet with a wide mouth, bounded by low hills along its lower portion, but the upper part, extending into a canyon, is similar to a Norwegian fjord. The inlet is approximately fifteen miles in length, and varies in width from five miles at the widest part to about one mile along Squally Reach in the canyon. The greatest depth of 231 meters is just within the entrance of Squally Reach. Because there is a relatively shallow sill at a depth of 62-73 meters at the mouth, the bottom water is stagnant, being practically devoid of oxygen and reeking with hydrogen sulfide. Carter (1932) gives 90 meters as the depth at which the water becomes stagnant both physically and chemically. In 1954 there was practically no oxygen below 75 meters.

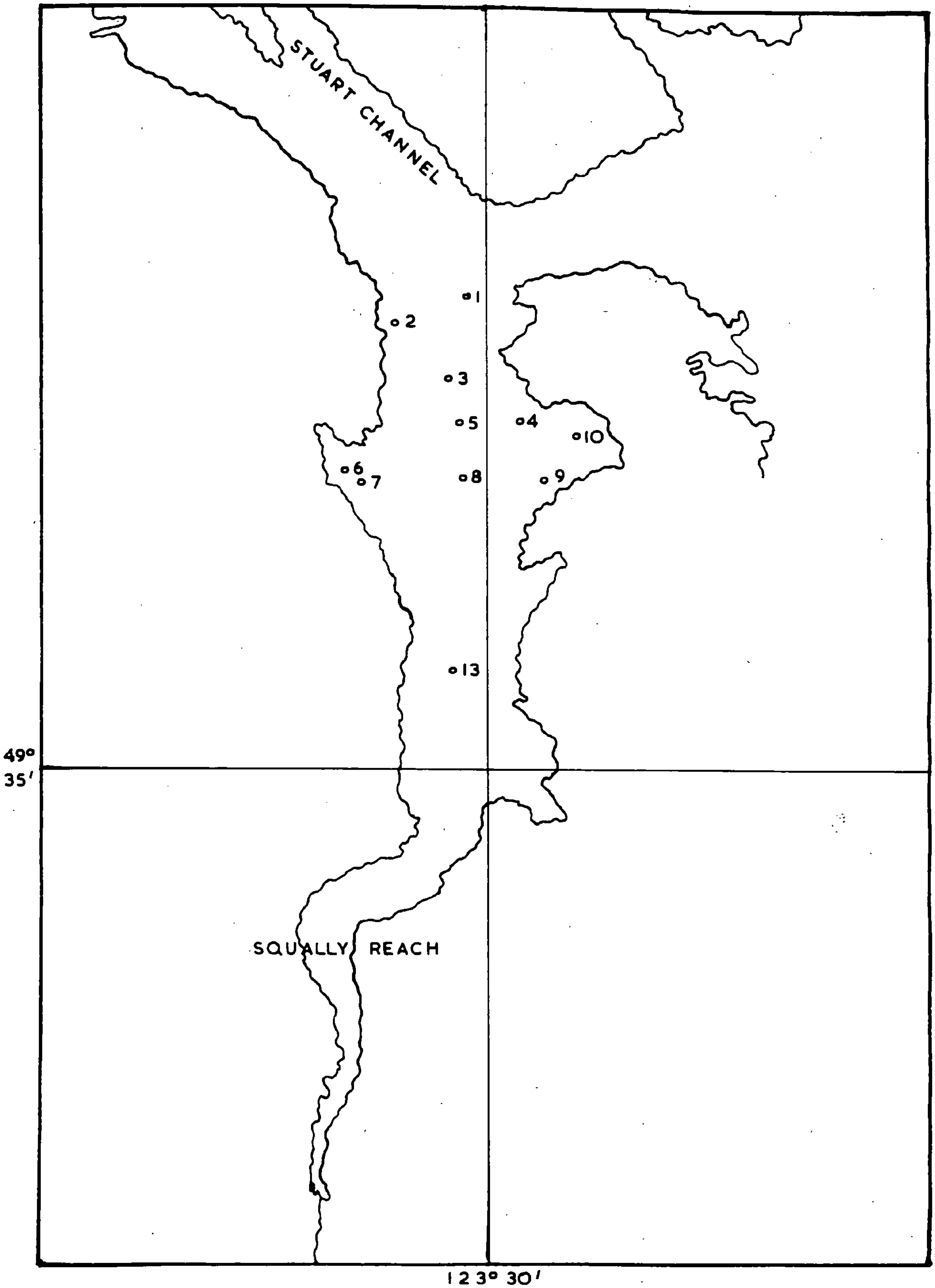
The water in the inlet is comparatively warm at the surface, the summer surface temperature ranging between 13.4-15°C, with a sharp drop of two to three degrees three meters below the surface. The bottom temperature drops another 2-5°C. The salinity is lower than for the Pacific Ocean in this latitude (Sverdrup, et al, 1952, give 33.64 °/oo for the Pacific Ocean at 40°N), and in August it varies from 29.20 °/oo at the surface to 31.43 °/oo at the bottom. A small river enters the Inlet at the head and several streams add some fresh water, if only during the spring freshet, but most of the fresh water probably enters by way of the mouth from Stuart Channel, down which an almost continuously flowing ebb tidal current brings fresh water from the huge Fraser River, from various smaller rivers, and the run-off of the abundant rainfall of the region.

The material from Saanich Inlet was collected on May 21 and 22, 1954. Twenty stations were occupied, and most of the samples collected were examined. Unfortunately only eleven stations could be located on the map (Map II), the data not having been assembled for the remaining ones. Most of the eleven stations are toward the entrance of the Inlet, one being in the middle, but none at the head. The Saanich plankton samples look different from those taken from any other region. All of them are a bright, clear-green color and almost gelatinous in consistency, due to the presence of great numbers of fine green algae.

Because each sample from Saanich was preserved in two or three bottles, a method of counting was used for most of these stations different from that used in all the other areas. For only two of the eleven stations was the entire sample examined. For the others, one of the bottles was selected at random and the number of specimens present determined. This number was then multiplied by two or three, as the case might be, to approximate the probable number of chaetognaths present in the complete sample. Counts were made for the entire sample for the hauls that could not be located geographically.

Some interesting observations can be made from the data obtained for the stations shown on the map. Along the deeper mid-channel at stations 1, 3, 5, 8, and 13, S.elegans occurred fairly abundantly, and many specimens were maturing or mature. Out of the 341 estimated specimens caught at these five stations, 171 or 50% were immature, 29 or 9% were maturing and had seminal vesicles and rod-like ovaries, and 141 or 41% were fully mature. At the other stations, immature individuals were abundant, with the exception of the shallow hauls made at stations 6 and 10 in bays at opposite sides of the inlet. At station 9, near shore but in deeper water, all stages were fairly abundant. At some of the stations that could not be located, and which were possibly in the upper part of the Inlet, the population was quite dense, and a large number of mature specimens was present. Since all the maturity stages occurred in significant numbers in Saanich Inlet, one can conclude that the Inlet provides a suitable habitat for the species, and that S.elegans is probably endemic.

E.hamata was also present in the Inlet, though in small numbers. Only twenty-three specimens, all immature and rather large (13-17 mm.) were taken in the deeper hauls. One must assume, since there were neither mature specimens nor very small ones, that the ones taken probably found their way into the inlet by way of Stuart Channel and were not indigenous to the inlet.



MAP II. SAANICH INLET - STATIONS

Position	Station	Hauls per Sta.	Depth in Meters	*Sagitta elegans* Numbers & Maturity	Size in mm.	*Eukrohnia hamata* Numbers & Maturity	Size in mm.
Channel	1	1	66	Mature 1x3= 3 Immature 10x3= 30	22.5 4.5 - 13	-	
N ↓	3	1	99	Mature 35 Maturing 15 Immature 41	21.5 - 29 14 - 20 5.5 - 14.5	-	
	5	1	155	Mature 41x2= 82 Maturing 1x2= 2 Immature 20x2= 40	17 - 26 16.5 5.5 - 14	-	
	8	1	192	Mature 5x3= 15 Maturing 3x3= 9 Immature 14x3= 42	21.5 - 24 17 - 20.5 7 - 14	Immature 1x3= 3	14
S	13	1	123	Mature 2x3= 6 Maturing 1x3= 3 Immature 6x3= 18	20 - 20.5 17.5 7.5 - 13.5	Immature 2x3= 6	13 - 15
West N ↓	2	1	80	Maturing 2x2= 4 Immature 43x2= 86	13 - 14 4.5 - 16.5	-	
	6	1	18	Immature 9x2= 18	4.5 - 7.5	-	
S	7	1	40	Immature 49x2= 98	4.5 - 12	-	
East N ↓	4	1	42	Immature 75	4 - 14	-	
	10	1	22	Immature 7x2= 14	4.5 - 8.5	-	
S	9	1	84	Mature 5x2= 10 Maturing 13x2= 26 Immature 37x2= 74	21.5 - 27 14 - 20.5 6.5 - 15.5	-	

Table 1 - SAANICH INLET Distribution of Chaetognaths (Con. next page)

Position	Station	Hauls per Sta.	Depth in Meters	Sagitta elegans Numbers & Maturity		Sagitta elegans Size in mm.	Eukrohnia hamata Numbers & Maturity		Eukrohnia hamata Size in mm.
Not located	12	1	-	Immature	4	6 - 10	-		
	14	1	229	Mature Maturing Immature	12 24 65	20.5 - 26 14 - 19 7 - 14.5	Immature	2	16
	15	1	-	Immature	133	7 - 14	-		
	16	1	-	Mature Maturing Immature	28 28 185	14 - 28.5 12 - 20 6 - 16	Immature	4	13 - 15
	17	1	-	Mature Maturing Immature	11 11 49	20 - 25 16 - 19 7 - 14	Immature	4	14 - 16
	18	1	192	Mature Maturing Immature	41 6 5	18 - 25.5 18 - 21.5 9.5 - 13.5	Immature	4	15 - 17
	19	1	139	Mature Maturing Immature	96 6 2	20 - 26 17 - 21 16 - 23	-		
	20	1	1.5	Immature	3	5.5 - 8	-		
		Totals		Mature Maturing Immature	339 134 983	) 1456	Immature	23	

Table 1 - SAANICH INLET Distribution of Chaetognaths

Cruise 54/1 ; May 21-22, 1954 ; C.N.A.V. Ehkoli ; Nineteen stations, nineteen hauls.

II INDIAM ARM

Map III; Table 2

Indian Arm is a long, narrow branch of Burrard Inlet, near the city of Vancouver, extending about fourteen miles inland. At its widest point, not far from the mouth, it is a mile and a half across, but most of the arm is only about half a mile wide. The entrance is narrow, and like Saanich Inlet, it has a sill that is considerably shallower than the average depth. Consequently the bottom waters are stagnant. The sill is only 35 meters deep, and the average depth of the arm, according to Carter (1932), is from 146 to 183 meters, with depths up to 220 meters in parts where the mountain walls are the most precipitous.

The September surface temperature is very high compared with Saanich in August, the highest temperature being 19°C at the head. The surface water gradually cools as it progresses toward the mouth, where the temperature was only 15°C. The water is colder at the bottom, dropping to about 8°C in the deepest part in the middle of the Arm. At three meters below the surface there is both a distinct thermocline and halocline. The temperature drops suddenly four to five degrees, and the salinity increases 4-6 °/oo. The salinity varies from 18.06 °/oo at the surface at the head to 28 °/oo in the deepest water. At the bottom the water is even less saline than the surface water of Saanich. The low salinity results from the large volume of water poured in at the head by the Indian River.

The material from Indian Arm was collected on September 4 and 5 in 1953. There were seven stations in four areas, twelve hauls being made. Duplicate stations occupied on two successive days were located near the entrance, in the middle, and near the head. A single station was at the very upper end.

S.elegans constitutes the entire chaetognath population of Indian Arm, this inlet being one of three among all the areas sampled where no E.hamata were taken. The distribution of S.elegans was especially interesting. In one haul near the entrance there were no chaetognaths and in a haul in the same location the next day there were only three large, immature ones, while halfway up the Arm, S.elegans was both large and abundant and in all maturity stages. Near the head there were fewer individuals, but more of them were mature. The immature ones were mostly small. At the station near the extreme tip of the Arm, where the water was only forty-nine meters deep, chaetognaths were completely absent.

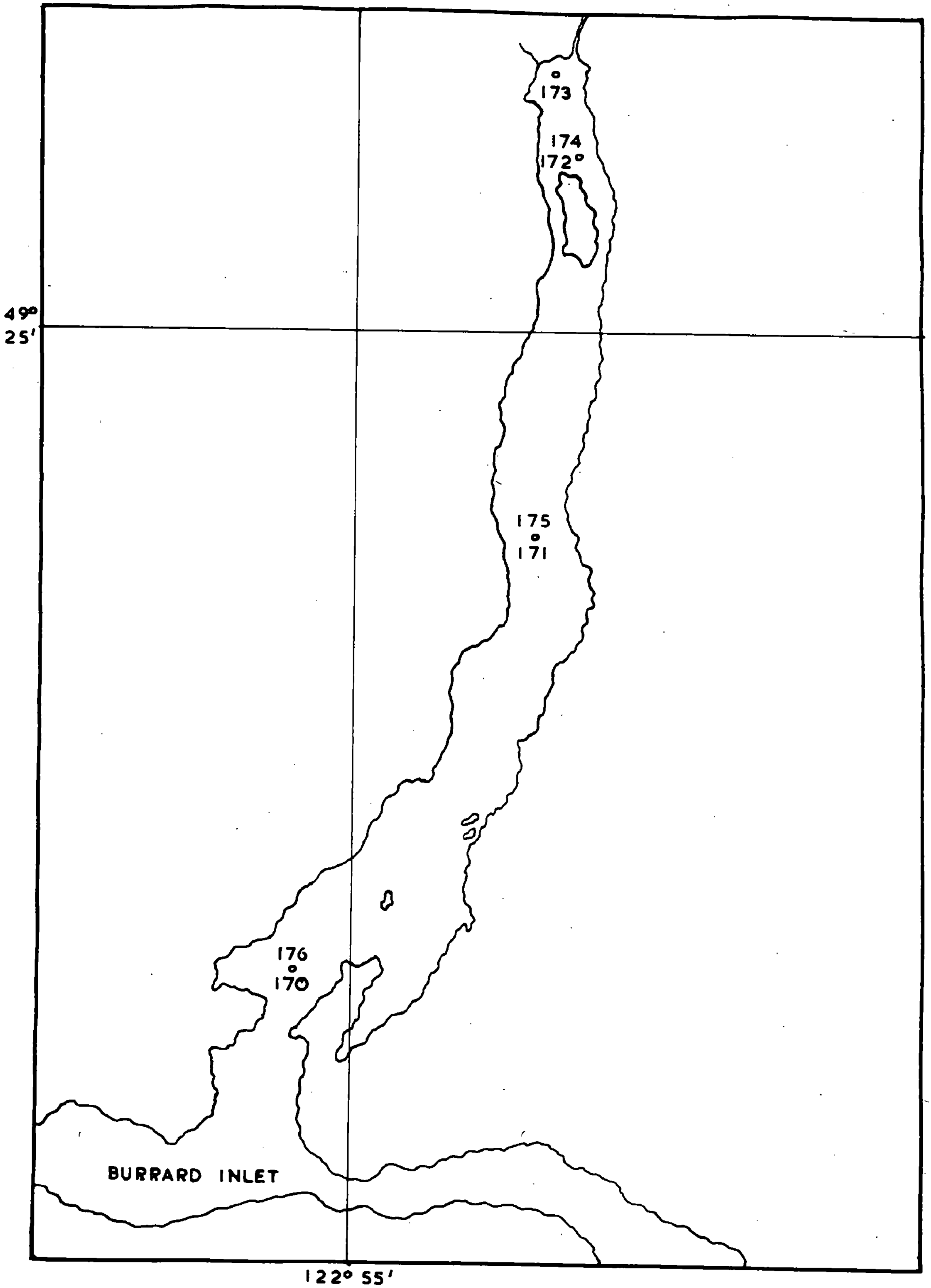
At the location approaching the head, seven hauls in all were made. The proportions for the different maturity stages were about the same in every haul made. The average for the six hauls at station 174 was 9 mature, 4 maturing, and 43 immature, as compared with the one haul in the same location at station 172 earlier in the day, in which there were 7 mature, 7 maturing, and 44 immature individuals.

When collecting material with vertical hauls it is impossible to know at what depth the specimens were living, but in the middle of the Arm where the hauls were deepest, as previously stated, S.elegans was both largest and most abundant. It is known that the larger specimens go into the deeper water. However, great depths may not be a factor, especially when the bottom waters are stagnant.

Perhaps the length of the life cycle in combination with the rate of flow of the currents in the Arm determine at what point the different sizes and stages will be at any given time. The surface water flows toward the mouth, and Carter (1932) states that the progress from the head toward the sea is slow. The deep current flowing in the opposite direction would then likewise be slow. Since there were more mature specimens at the head than anywhere else, it may be that as the deep current moves slowly toward the head, the large immature specimens are carried that way, and are ready for spawning by the time they reach the head. The younger forms live near the surface (Huntsman,1919) and would travel in the direction of the surface current. These young individuals may attain the age when they seek greater depths by the time they reach the middle of the Arm. And so the cycle continues, few individuals ever reaching the mouth of the inlet. The circulation then would account for the distribution of the indigenous population.

The location in the inlet of the various maturity stages could also be explained by Meek's (1928) observation that at spawning time S.elegans seeks the more shallow (less saline?) inshore waters, and that the maturing individuals migrate outward into deeper water.

The high temperatures from top to bottom in the shallow



Map III. INDIAN ARM - Stations

Position	Station	Hauls per Sta.	Depth in Meters	*Sagitta elegans* Numbers & Maturity		*Sagitta elegans* Size in mm.
Mouth	176	1	70	Immature	3	23 - 25
Middle	171	1	209	Mature	6	19 - 21
				Maturing	4	16 - 22
				Immature	242	13.5 - 25
	175	1	217	Mature *	6+	13 - 22
				Maturing *	3+	22 - 24
				Immature *	182+	11 - 26
Head	172	1	78	Mature	7	16 - 22
				Maturing	7	14 - 18
				Immature	44	9 - 22
	174	1	86	Mature	52	18 - 23
				Maturing	21	13 - 18
				Immature	260	8 - 25

* Some had been removed.

Totals	Mature	71	837
	Maturing	35	
	Immature	731	

Table 2 - INDIAN ARM Distribution of Chaetognaths

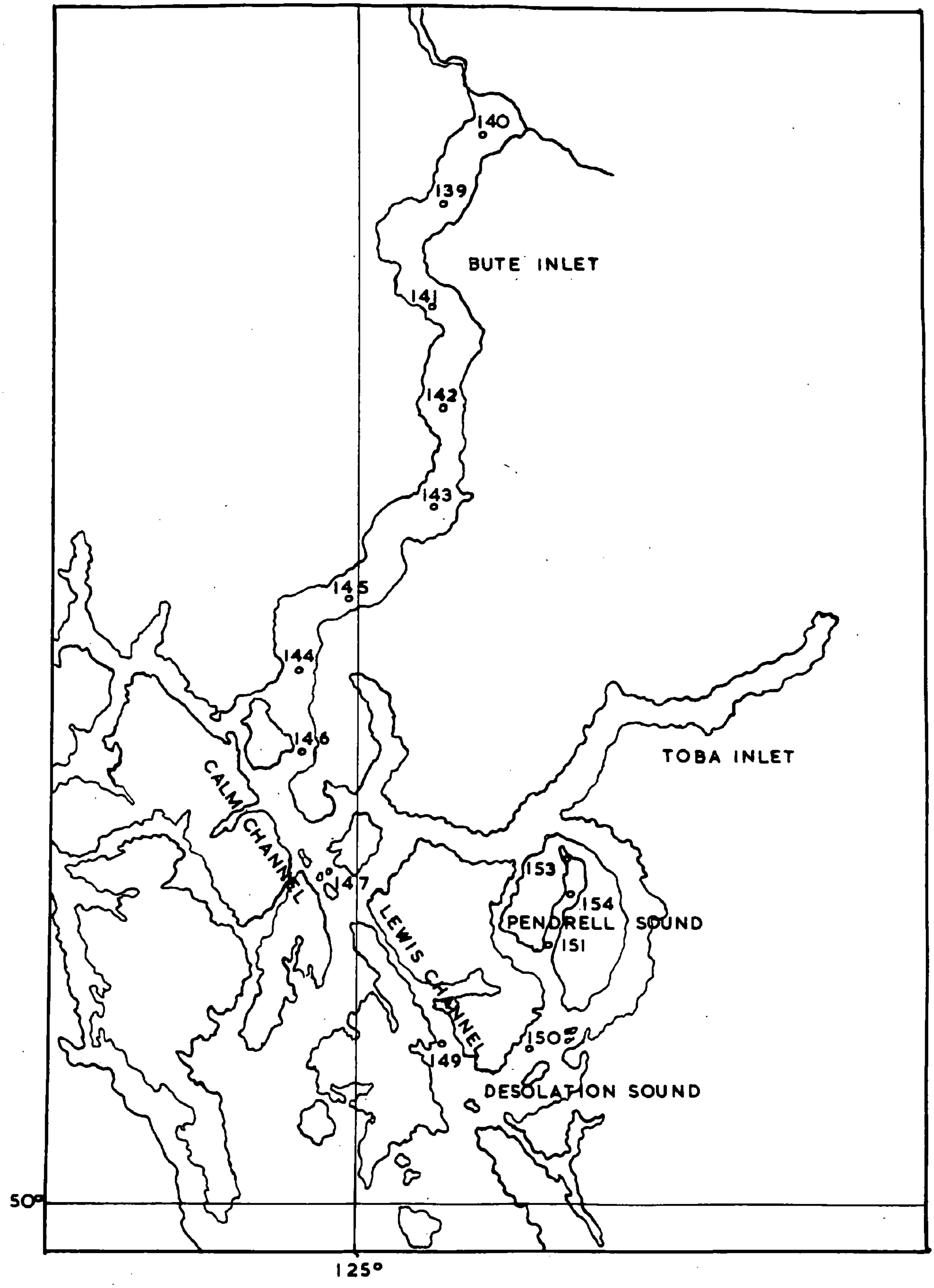
Cruise 53/7 ; September 4-5, 1953 ; C.G.M.V.Cancolim II ; Seven(four) stations, twelve hauls.

water toward the mouth, could be a barrier to the chaetognaths in the Arm, as well as one preventing the entrance of migrants from the outside, including occasional visitors like the oceanic E.hamata. Polution of the waters near the entrance by sewage from the city of Vancouver could be another factor.

III PENDRELL SOUND

Map IV; Table 3

Pendrell Sound, seven miles long and one-half to one and a quarter miles wide, almost bisects the westernmost of the two Redonda Islands at the head of the Strait of Georgia. The depths to which the vertical hauls in the present survey were made indicate that the bottom slopes gradually from the head to a depth of 347 meters at the mouth. The surface temperatures were high, though lower than the maximum in Indian Arm a month later. At the head of Pendrell, the temperature at the surface was 16.7°C, and it dropped almost exactly one degree toward the mouth. Unlike Indian Arm, there was no thermocline, the temperature decreasing gradually to just over 8°C at the bottom. The water was less saline at the surface, but was least saline at the mouth, rather than at the head. Vertically the salinity also varied gradually from 18.24 ^{o}/oo at the surface to 30.80 ^{o}/oo at the bottom. There is no river discharge into the Sound, the fresh water supposedly entering by way of Waddington Channel from nearby Toba or Bute Inlets. An exploratory survey made by the Institute of Oceanography of the University of British Columbia



MAP IV. PENDRELL SOUND, CHANNELS, AND BUTE INLET - STATIONS

Position	Station	Hauls per Sta.	Depth in Meters	*Sagitta elegans* Numbers & Maturity		*Sagitta elegans* Size in mm.
Mouth	151	1	347	Immature	49	11 - 20.5
Middle	154	1	240	Immature	6	12 - 16
			Total	Immature	55	

Table 3 - PENDRELL SOUND Distribution of Chaetognaths

Cruise 53/7 ; August 24-25, 1953 ; C.G.M.V.Cancolim II ; Three stations, three hauls.

Position	Station	Hauls per Sta.	Depth in Meters	*Sagitta elegans* Numbers & Maturity		*Sagitta elegans* Size in mm.	*Eukrohnia hamata* Numbers & Maturity		*Eukrohnia hamata* Size in mm.
SE	150	1	439	Immature	65	12 - 19.5	-		
SW	149	1	183	Immature	58	10.5 - 23	-		
North	147	1	366	Mature Maturing Immature	3 2 76	22 - 27 19 - 21 9 - 22.5	Immature	1	17
Totals				Mature Maturing Immature	3) 2) 199)	204	Immature	1	

Table 4 - CHANNELS NORTH END STRAIT OF GEORGIA Distribution of Chaetognaths

Cruise 53/7 ; August 23, 1953 ; C.G.M.V. Cancolim ; Three stations, three hauls.

in the summer of 1951 also established the fact that there was very little circulation in the Sound.

Pendrell Sound was one of the three areas where S.elegans was the only chaetognath present. However, the distribution of this species was unique in that the population was all concentrated toward the entrance, and all specimens taken were small and immature, ranging in size from 11-20.5 millimeters. The chaetognaths in the Sound must have entered at the mouth through random swimming. Lack of food supply toward the head may have been a factor in preventing deeper penetration into the Inlet. Examination of the specimens during this survey showed copepods to be an important source of food for chaetognaths, and in Pendrell Sound, the copepods are also concentrated toward the entrance. (Le Brasseur,1954, unpub.).

IV CHANNELS NORTH END STRAIT OF GEORGIA

Map IV; Table 4

Three hauls were made on August 23, 1953 in the channels at the north end of the Strait of Georgia off the Redonda Islands and leading to Bute Inlet. The stations were located at intervals covering a distance of fourteen miles. One was in Desolation Sound, off the southern shores of the Redonda Islands, another at the entrance of the narrow Lewis Channel, on the west side of the same islands, and the third in Calm Channel, off the mouth of Bute Inlet. The depths of the hauls indicate that the channels are fairly deep, the deepest haul being made in Desolation Sound at a depth of 439 meters. The surface temperatures were all higher than those just within Bute Inlet and reach 16.4^{o}C at the entrance of Lewis Channel. At this station the temperature decreased gradually from the surface to 8.4^{o}C at the bottom, the salinity also increasing gradually, but at the station farther north in Calm Channel, the surface water was four degrees warmer than it was at a depth of three meters. In Desolation Sound, the warmest water was ten meters below the surface. The waters from top to bottom for all stations were less saline than the open Pacific, increasing from 16.66 $^{o}/oo$ at the surface to 30.90 $^{o}/oo$ at the bottom. The tidal currents in all three locations are weak (Great Britain. Hydrographic Office, 1951), and the temperature and salinity data do not give evidence of much mixing.

At the two southern stations, as in Pendrell Sound, S.elegans only was found, and though it was present in some numbers, all individuals were immature. In Calm Channel, all maturity stages of this species occurred, and in addition one rather large immature E.hamata was taken. Since both species occur in Bute Inlet in all maturity stages, and the water conditions in Calm Channel are similar to those in Bute, it is not surprising to find a similar population just outside the mouth of the Inlet.

V BUTE INLET

Map IV; Table 5

Bute Inlet, not far beyond the northern end of the Strait of Georgia, is one of the long, narrow, deep inlets characteristic of the British Columbia coastline. Only one to two miles wide, Bute Inlet extends forty-six miles inland between mountains that rise abruptly 5000-8000 feet to snow-covered peaks. It is one of the deeper inlets along the coast, the deepest haul reaching to 636 meters. There is no pronounced sill at the entrance, though the bottom of Calm Channel off the mouth, is over 200 meters above that of Bute just inside the mouth. There is at most 41% less oxygen at 600 meters than there is at the surface, and the bottom is definitely not stagnant.

At the head of the Inlet there are two valleys, and a large river of glacial origin flows out of each, making the head waters of Bute silty. A layer of this cold, "milky," water of low salinity ten meters deep flows seaward over a warmer, more saline layer below. The surface temperatures in August were from 7-8.5°C in the upper reaches, while ten meters below the surface, the temperature was around 10°C. Below the thermocline, the temperature decreased gradually to 8°C at the bottom. Toward the middle of the Inlet the thermocline was only three meters below the surface, and the surface had warmed to 10°C with the layer below only just over one degree warmer. Pickard (1932) states that seasonal cooling and warming penetrate to about 300 feet

(91.4 meters), but that below this depth changes appear to take place slowly and probably irregularly.

The water at the head of Bute Inlet is almost fresh. At station 140 in August, the surface salinity was 0.61 $^{o}/oo$. Though the surface salinity increases as the water flows toward the entrance, it was only 7.14 $^{o}/oo$ at the mouth. At the ten-meter level below the surface at station 140, the salt content increased sharply to 27.36 $^{o}/oo$. During the progress of the water toward the mouth, the difference in salinity of the surface and under layer becomes less pronounced, until near the mouth there is a difference of only five parts per thousand. At all stations the deep water was between 30 and 31 $^{o}/oo$.

As the surface water flows out of Bute Inlet the replacement from Calm Channel enters at greater depths. The current in the deep water then flows toward the head, the direction of flow being opposite to that of the surface current.

Twenty-six hauls were made at eight stations in Bute Inlet from August 20 to 23 in 1953. These stations were approximately equidistant along the entire length of the inlet. Both S.elegans and E.hamata occurred in all maturity stages. S.elegans was abundant only toward the mouth, though almost all of the specimens taken were rather small and immature. In the center of the Inlet the population was not large, but a few individuals were mature or maturing. Toward the head, though even fewer specimens were taken, 30% of them were maturing. Neither was E.hamata present in great numbers, but conditions in the Inlet appear to be favorable to the extent that most of the few individuals taken were maturing. Also, the only fully mature specimen obtained throughout the entire survey (Plate II) came from the middle of Bute Inlet. All of the specimens of E.hamata taken were in the lower half of the Inlet, and most of these were toward the mouth.

The explanation of the distribution of S.elegans in Bute Inlet might be similar to that for the species in Indian Arm, though the mouth is not blocked by a shallow sill, and the haul in Calm Channel below the mouth shows that the distribution is continuous with the outside waters. Considering the Inlet only, toward the mouth the animals were immature but not very small and may have reached the stage where they had sought deeper waters. These specimens then would be at a depth at which the current would be flowing toward the head. As they progressed in that direction, they would be maturing, eventually coming near the surface to spawn farther up the inlet. The young then would be in the upper waters moving seaward, where they would later migrate into the deeper water near the mouth.

The distribution of E.hamata appears to be quite random. Perhaps migrants entering at the mouth, because conditions are suitable in the Inlet, are able to mature as they progress up the Inlet with the current in the deep water. Since the inlet is a long one, the time for spawning may arrive before they penetrate the waters near the head. Then when spawning takes place, the young near the surface are swept out the mouth in the seaward flowing surface current.

Position	Station	Hauls per Sta.	Depth in Meters	*Sagitta elegans* Numbers & Maturity		*Sagitta elegans* Size in mm.	*Eukrohnia hamata* Numbers & Maturity		*Eukrohnia hamata* Size in mm.
Mouth	146	1	594	Immature	181	20 - 23	Maturing	4	17 - 19
↓	144	5	600	Maturing	1	23	Maturing	2	23 - 27
				Immature	175	12 - 23.5	Immature	6	14 - 17
	145	1	636	Immature	13	14 - 20	-		
	143	8	600	Mature	2	20 - 24	Mature	1	14
				Maturing	4	15 - 18	Maturing	2	13 - 15
				Immature	115	10 - 21	Immature	1	11
	142	1	500	Maturing	4	18 - 23	Immature	1	13
				Immature	10	12.5 - 18			
	141	1	411	Maturing	2	18.5 - 21	-		
				Immature	6	13 - 19			
	139	8	300	Maturing	27	16 - 25	-		
				Immature	45	10.5 - 18			
Head	140	1	200	Maturing	1	21	-		
				Immature	8	12.5 - 17			
		Totals		Mature	2	)	Mature	1	)
				Maturing	39	) 594	Maturing	8	) 17
				Immature	553	)	Immature	8	)

Table 5 - BUTE INLET Distribution of Chaetognaths

Cruise 53/7 ; August 20-23, 1953 ; C.G.M.V.Cancolim II ; Eight stations, twenty-six hauls.

Had the object been only to discover the distribution of S.elegans and E.hamata in the Inlet, it would not have been necessary to examine all the hauls made at three of the stations where the ship was anchored for a long period of time, hauls being made at regular intervals over a period of twenty-four hours. However, S.planctonis had been reported from the area, a specimen sent by Mr. Le Brasseur to Dr. Thomson in Australia having been identified as that species. A very thorough examination of all twenty-six hauls failed to locate another specimen. It would be rather unusual for this deep sea species to survive a journey into the less saline inland waters, though in the future, perhaps another specimen could again be taken unexpectedly somewhere in the British Columbia coastal waters.

VI QUEEN CHARLOTTE STRAIT

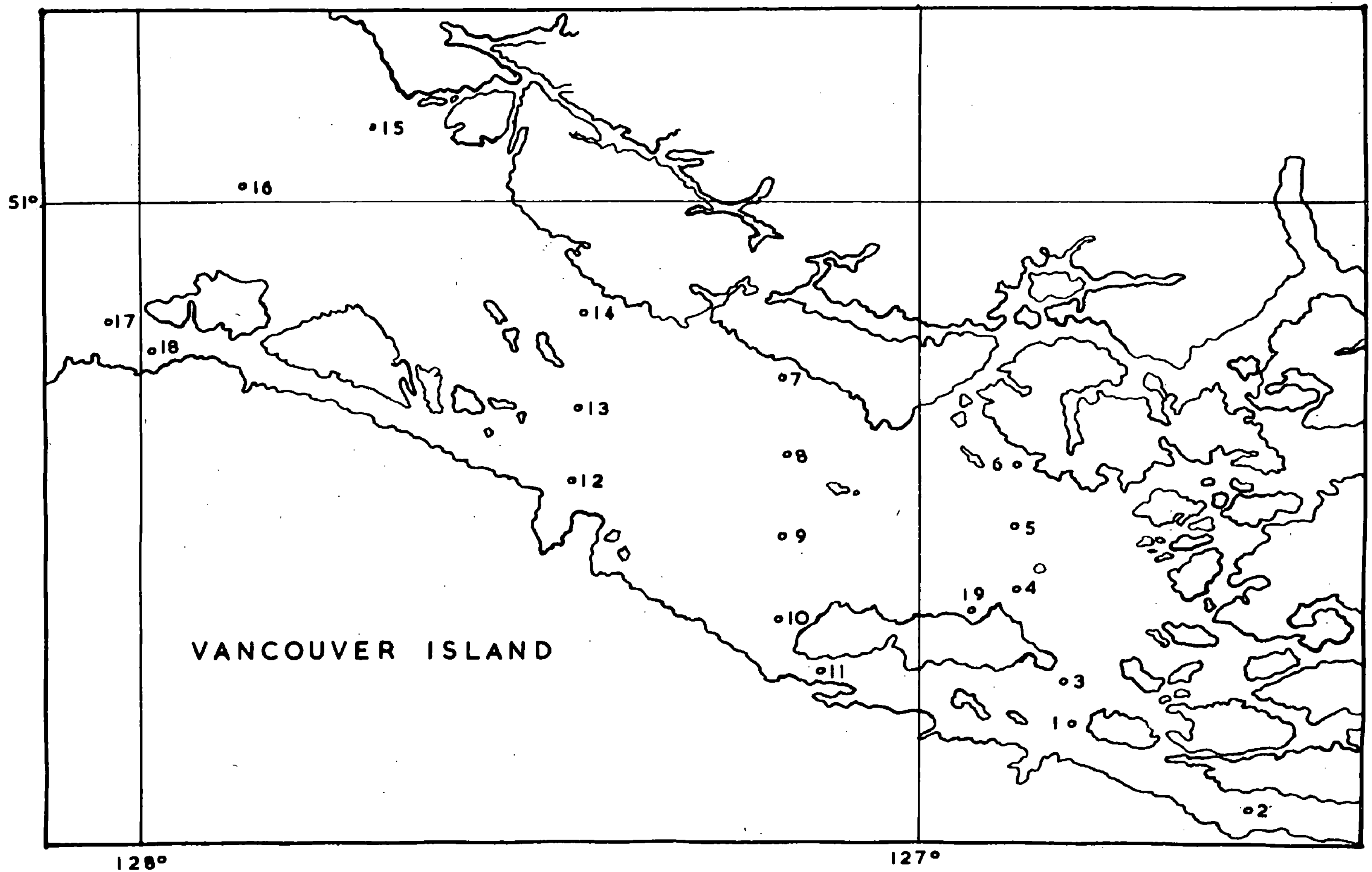
Map V; Table 6

Queen Charlotte Strait, between the northern portion of Vancouver Island and the British Columbia mainland, opens on the oceanic Queen Charlotte Sound. At the other end is the narrow, two and one-half mile wide Johnstone Strait leading to Seymour Narrows, Discovery Pass, and the Strait of Georgia. Queen Charlotte Strait is sixty-two miles long and twelve to twenty miles wide. It is not very deep in most parts, averaging less than one hundred meters, though at one point near the east end of Nigei Island not far from the entrance there is a deep of 406 meters. Another deep of 470 meters is just within the entrance of Johnstone Strait.

The surface temperature of 8.5-9.7°C in Queen Charlotte Strait in June is about the same as the surface temperature of the Pacific Ocean in the same latitude, and the bottom is only one to two degrees colder. The Strait is slightly less saline than the Ocean, varying from a maximum of 31.63 °/oo at the surface near the entrance to 33.47 °/oo at the bottom. The waters are thoroughly mixed by the tidal currents, the flood entering from Queen Charlotte Sound and flowing along the southern shores, and the ebb passing out along the northern side.

There were nineteen hauls made at nineteen stations in Queen Charlotte Strait between June 12 and 16 in 1953. S.elegans occurred in every haul, and there was at least one immature E.hamata in most hauls made in the channel, though there were none near the coastlines.

At the ocean end of the Strait, the specimens of S.elegans taken were small and immature. A greater number were taken in the central part of the Strait and quite a few of these were mature. The mature ones were both at mid channel and along the north shore. Along the south shore the specimens were immature. It would appear that the animals were maturing in the mixed waters of the ebb tidal current, while the immature forms are more widely distributed. As previously stated, other investigators have found that S.elegans moves shoreward into the more mixed coastal waters to spawn, and the distribution picture in Queen Charlotte Strait seems to be in accord with those findings.



MAP V. QUEEN CHARLOTTE STRAIT - STATIONS

Position	Station	Hauls per Sta.	Depth in Meters	Sagitta elegans Numbers & Maturity		Sagitta elegans Size in mm.	Eukrohnia hamata Numbers & Maturity		Eukrohnia hamata Size in mm.
Mid-chan. W	16	1	91	Immature	8	5.5 - 9	Immature	1	9
↓	13	1	91	Immature	4	4 - 8.5	-		
	8	1	91	Mature Maturing Immature	17 20 28	18.5 - 23 15.5 - 19 7 - 16	Immature	1	7.5
	9	1	71	Maturing Immature	15 55	15 - 20.5 1 - 15	Immature	1	9.5
	5	1	91	Mature Maturing Immature	4 6 23	18.5 - 25 18 - 19 6.5 - 18	Immature	1	16
	4	1	91	Mature Maturing Immature	7 12 25	19 - 23.5 14 - 19 1.5 - 14.5	Immature	3	9 - 12
	3	1	65	Maturing Immature	4 40	15 - 19 3 - 14	-		
E	1	1	91	Mature Immature	1 8	22 8.5 - 12.5	-		
Johnstone Str.	2	1	66	Maturing Immature	9 35	16 - 19 2 - 16.5	-		

Table 6 - QUEEN CHARLOTTE STRAIT   Distribution of Chaetognaths

(Con. on next page)

Position	Station	Hauls per Sta.	Depth in Meters	*Sagitta elegans* Numbers & Maturity		Size in mm.	*Eukrohnia hamata* Numbers & Maturity		Size in mm.
N Shore W	15	1	91	Immature	16	2.5 - 12	-		
↓	14	1	91	Mature Maturing Immature	10 12 27	19 - 22.5 17 - 20 9 - 18.5	-		
↓	7	1	91	Mature Maturing Immature	2 1 8	23 17 7.5 - 11	-		
E	6	1	91	Maturing Immature	1 16	16 5 - 15.5	-		
S Shore	17	1	20	Immature	1	11.5	-		
W	18	1	71	Immature	4	1 - 13	-		
↓	12	1	91	Mature Immature	1 13	20 6 - 10.5	-		
↓	10	1	91	Immature	18	3 - 11	Immature	1	7.5
E	11	1	46	Immature	43	1.5 - 13	-		
North Malcolm	19	1	10	Immature	4	1.5 - 4	-		
		Totals		Mature Maturing Immature	42) 80) 376)	498	Immature	8	

Table 6 - QUEEN CHARLOTTE STRAIT Distribution of Chaetognaths

Cruise 53/2 ; June 12-14,16, 1953 ; C.G.M.V.Cancolim II ; Nineteen stations, nineteen hauls.

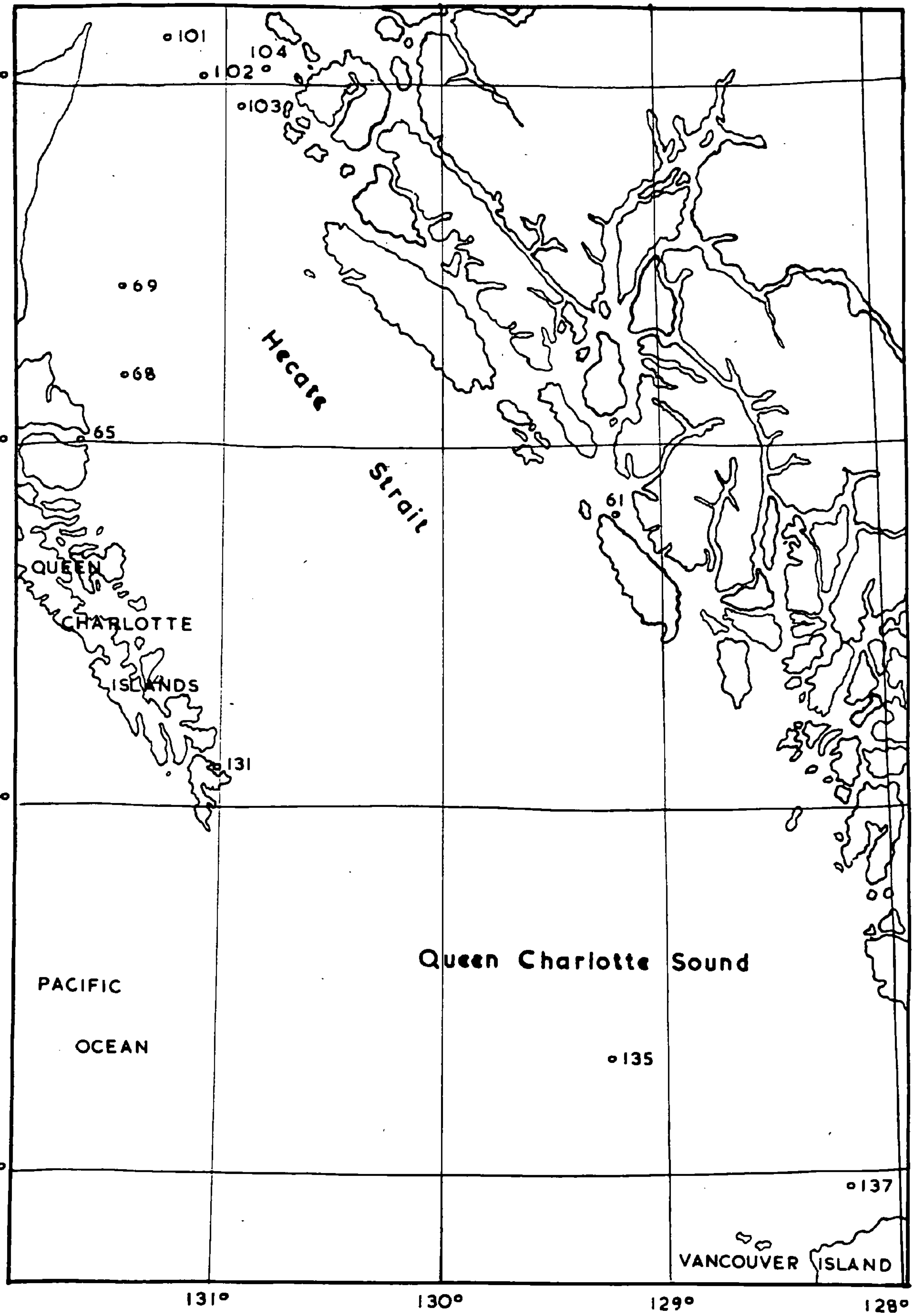
Since the eight specimens of E.hamata taken were small, immature and scattered near mid-channel, it would seem that they were migrants brought in by the flood tide.

VII QUEEN CHARLOTTE SOUND

Map VI; Table 7

Queen Charlotte Sound is the open ocean area between Vancouver Island and the Queen Charlotte Islands. At the north is Hecate Strait. The Sound is about seventy-five miles long and up to one hundred and fifteen miles wide. Since it is over the continental shelf it is not extremely deep, the greatest depth recorded in the 1953 cruise being 400 meters on the ocean side. The average depth is probably 150-200 meters less. The surface temperature is rather high compared with Queen Charlotte Strait, varying from just over 12°C near the Queen Charlotte Islands to a high of 15°C in the middle, and a lower 11°C near the entrance of the Strait. There is a gradual decrease toward the bottom, and out from shore the bottom temperature is about 5.5°C, which is one to two degrees colder than the bottom waters of the Strait. The water is also more saline, approaching the salinity of the open Pacific. The coastal current prevails and sets northwestward.

Only two hauls made in the region on August 10, 1953 were available for examination. In one shallow haul of 42 meters, just outside the entrance of Queen Charlotte Strait, a swarm of very small immature S.elegans was found. Few animals



MAP VI. QUEEN CHARLOTTE SOUND AND HECATE STRAIT - STATIONS

Position	Station	Hauls per Sta.	Depth in Meters	Sagitta elegans Numbers & Maturity	Sagitta elegans Size in mm.	Eukrohnia hamata Numbers & Maturity	Eukrohnia hamata Size in mm.	Sagitta decipiens Numbers & Maturity	Sagitta decipiens Size in mm.
Middle	135	1	249	Maturing 2 Immature 139	15 - 22 5.5 - 21	Immature 58	5 - 16	Maturing 3	12 - 12.5
Coastal	137	1	42	Immature 201	2 - 13	-		-	
Totals				Maturing 2) Immature 340) 342		Immature 58		Maturing 3	

Table 7 - QUEEN CHARLOTTE SOUND Distribution of Chaetognaths

Cruise 53/6 ; August 10, 1953 ; C.G.M.V.Cancolim II ; Two stations, two hauls.

Position	Station	Hauls per Sta.	Depth in Meters	Sagitta elegans Numbers & Maturity	Sagitta elegans Size in mm.	Eukrohnia hamata Numbers & Maturity	Eukrohnia hamata Size in mm.
East	103	1	36	Immature 2	6.5 - 7	-	
	104	1	75	Immature 7	6 - 25	Immature 1	17
Totals				Immature 9		Immature 1	

Table 8 - HECATE STRAIT Distribution of Chaetognaths

Cruise 53/6 ; July 16-30, 1953 ; C.G.M.V.Cancolim II ; Nine stations, ten hauls.

that small were taken in the Strait. Another swarm of these very small individuals was encountered at the other station farther off shore, and in addition, with them were great numbers of equally small E.hamata. In the inshore hauls only larger specimens had been taken, and the population had been scattered and sparse. Still more interesting was the discovery of three very fine, twelve-millimeter specimens of S.decipiens with well-developed ovaries, but no seminal vesicles. The haul at 249 meters was not an especially deep one, and it would hardly be expected that a species of the deep ocean at that stage of development would be found there. Ritter-Zahony (1911b) gave the range of S.decipiens as 200-1200 meters, the young inhabiting the epiplankton and the mature ones the mesoplankton. With the young of the coastal S.elegans and the oceanic E.hamata both in abundance, plus the deep sea S.decipiens, the station appears to be approaching the border-line between the oceanic and coastal fauna.

VIII HECATE STRAIT

Map VI; Table 8

Hecate Strait, between the Queen Charlotte Islands and mainland British Columbia, is thirty to eighty miles wide and about one hundred and fifty miles long. It is not very deep, especially toward the north, where the depth is at most only 18-36 meters. It deepens toward the south to a maximum of around 183 meters, but the depths are very irregular. The surface temperature in July was about 12-13°C, which is similar to the average in Queen Charlotte Sound, but the bottom temperature of the shallow water usually was only about two degrees colder at most. The surface salinity also was similar to that of the Sound, but there was very little increase toward the bottom. Tidal currents flow into and out of the Strait around both ends of the Queen Charlotte Islands. The flood currents meeting in the middle cause great turbulence and rips in some areas. Toward the northern end of the Strait the tidal streams are strong, but the southern end is so wide that the tidal streams are quite weak, except close to the coast of the Queen Charlotte Islands.

Ten hauls were made at nine stations in various parts of Hecate Strait from July 16 to 30 in 1953, but in only two hauls were chaetognaths present. At two stations on the east side near the northern entrance, ten specimens, all immature, were taken. Nine of these were S.elegans and one was E.hamata.

It is not surprising to find the chaetognath population sparse and almost wanting in such a shallow, warm area. At stations 103 and 104, where the only specimens were found, the bottom temperatures of 9.5 and 8.4°C were lower than at most of the other stations. E.hamata was at the station where the bottom was both deepest and coldest.

IX DIXON ENTRANCE

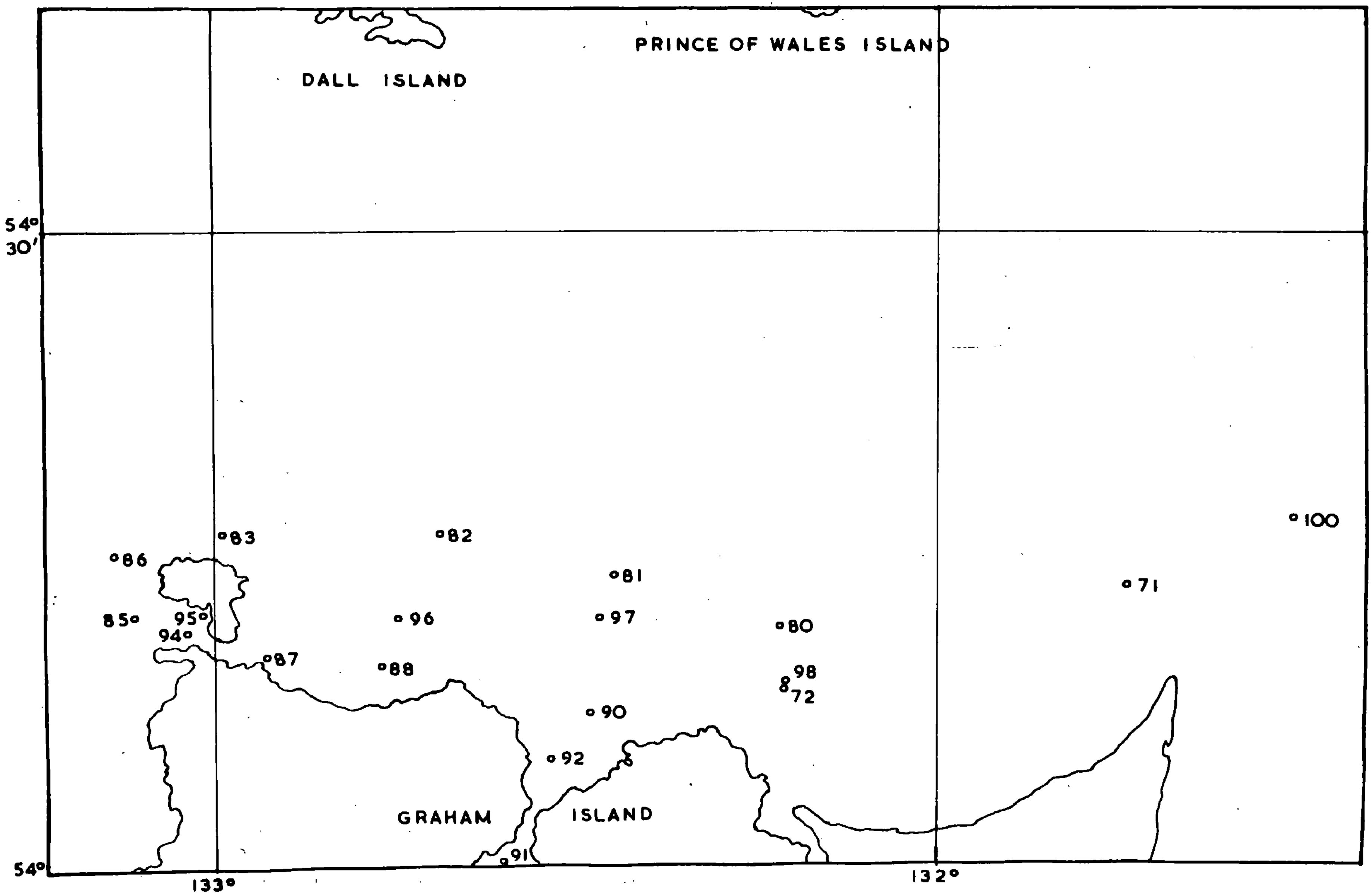
Map VII; Table 9

Dixon Entrance lies between Graham Island of the Queen Charlottes on the south and the Alaskan islands of Dall and Prince of Wales on the north. At the eastern end is Chatham Sound. The Entrance is about eighty-six miles long and thirty-five to forty-six miles wide. Along the Canadian shore it is not very deep, but in the channel there are depths of over 183 meters. The surface temperature between the channel and Graham Island varies from 11.8-13°C, and the bottom temperature of 5.5°C in the channel is five to six degrees colder than it is near the coast. The water is slightly more saline than it is in Queen Charlotte Strait, but not as saline as the open Pacific. The tidal streams in Dixon Entrance are somewhat irregular, and the passage is considered dangerous to navigation (Canada. Hydrographic and Map Service, 1945).

Nineteen hauls were made at nineteen stations in Dixon Entrance between July 19 and 29 in 1953. Five stations were about equidistant along the southern edge of the channel, and others were in various locations between the channel and the shores of Graham Island. The two westernmost of the channel hauls were deep ones made in the channel itself, and the other three were not far from the edge of it. Both S.elegans and E.hamata were found in large numbers in these channel hauls. Examination of Table 9 shows clearly that at the seaward end of the Entrance, both species were very abundant, and that there were quite a number of mature individuals. However, with progression eastward toward the mainland, both the population density and the number of mature animals decreases. At station 82 more specimens of S.elegans were taken than in any other locality in British Columbia. E.hamata was also present in unusually large numbers. Then at station 83, the number of S.elegans diminished, and there were still more E.hamata. In fact there were more E.hamata than S.elegans, reversing the proportion of the two species found in most hauls. Also some of the specimens of E.hamata were maturing. Another unusual thing about this haul was the presence of an excellent fourteen-millimeter specimen of the deep sea S.decipiens, besides three doubtful portions of this species. The undamaged specimen had well-developed ovaries, but no seminal vesicles.

The continental shelf is very close to the west coast of the Queen Charlotte Islands, and the evidence of these hauls in Dixon Entrance points to the conclusion that the region of the continental shelf may form the outer limit for S.elegans and mark the inner boundary of the region most favorable to the oceanic forms. At station 86, in a haul made in the open waters just outside Dixon Entrance, E.hamata only was found. This station could be beyond the limits of S.elegans.

The other hauls in Dixon Entrance were of interest, also, in the study of the distribution of the chaetognaths in the strait. The number of specimens decreased with distance from the channel and approach toward shore, and those that occurred were all immature. Along the coast, no chaetognaths were taken



Map VII. DIXON ENTRANCE – Stations

Position	Station	Hauls per Sta.	Depths in Meters	*Sagitta elegans* Numbers & Maturity	*Sagitta elegans* Size in mm.	*Eukrohnia hamata* Numbers & Maturity	*Eukrohnia hamata* Size in mm.	*Sagitta decipiens* Numbers & Maturity	*Sagitta decipiens* Size in mm.
Channel W	83	1	366	Mature 5 Maturing 3 Immature 270	12 - 25 22 - 25 4.5 - 35	Maturing 7 Immature 390	14 - 17 5 - 24	Maturing 1 Doubtful por. 3	14
↓	82	1	209	Mature 10 Maturing 4 Immature 1344	22 - 26 16 - 27 6 - 26	Immature 293	5 - 20	-	
↓	81	1	135	Mature 4 Maturing 3 Immature 481	23 - 25.5 17 - 23 2.5 - 27	Immature 88	4 - 18.5	-	
↓	71	1	128	Mature 3 Immature 322	23 - 26.5 4.5 - 26	Immature 31	5 - 17	-	
E	100	1	91	Mature 2 Immature 47	21 - 25 3.5 - 27	Immature 6	7 - 14	-	
Near Channel	97	1	65	Immature 43	7 - 23	Immature 12	6 - 14.5	-	
Near Channel	80	1	110	Immature 113	4 - 14	Immature 7	6 - 12	-	
Shoreward	96	1	46	Immature 1	16	-		-	
Shoreward	72	1	54	Immature 1	8	-		-	
Coastal Ent.	86	1	91	-		Immature 2	13 - 14	-	
				Mature 24) Maturing 10) Immature 2622)	2656	Maturing 7) Immature 829)	836	Maturing 1) Doubtful por. 3)	4

Table 9 - DIXON ENTRANCE Distribution of Chaetognaths (Stations with chaetognaths present).

Cruise 53/6 ; July 19-30, 1953 ; C.G.M.V.Cancolim II ; Nineteen stations, nineteen hauls.

in the nine hauls made. These hauls were in shallow water, but in other parts of British Columbia, equally shallow hauls disclosed large populations of chaetognaths. An examination of the data for the temperatures of all the stations in Dixon entrance, leads to the conclusion that in this part of the world chaetognaths do not occur where temperatures are relatively high. None occurred where the bottom temperature was much over 9°C. They were most abundant where the bottom temperature was 5.5°C, and as the temperature increased, the numbers of chaetognaths decreased. In Hecate Strait, where many hauls were made without finding chaetognaths, the bottom temperatures were also high. A few were taken where the bottom temperature dropped to 8.4-9.5°C.

X MASSET SOUND AND INLET

Map VIII; Table 10

Graham Island, the northernmost and largest of the Queen Charlotte Islands, is divided almost in two by Masset Sound and Inlet extending forty-three miles inland from Dixon Entrance. Both the Sound and Inlet are shallow and bordered by flat country and low hills. The entrance to Masset Harbor from Dixon Entrance is blocked by two sand bars which are covered by only five and one-half and four and one-half meters of water. The Sound is twenty-two miles long and only one-half to one mile wide. The average depth of the channel is from eighteen to thirty-seven meters, though in some places it is only thirteen meters deep.

There are a few deeper places, one near the entrance of Masset Inlet being 238 meters. Because only one station was located in the Sound, there is little information as to the temperature and salinity. At this one station near the entrance, the temperature was about 12.5°C and the salinity low at 27.5-28 °/oo. The tidal streams are strong in this long, narrow body of water.

Masset Inlet, running more or less east and west, is twenty-one miles long by three to seven miles wide. The eastern end is almost completely occupied by shoals with depths of only one to five and one-half meters. However the western end is deeper, and a depth of 101 meters is reached near station 89. The water is warm in most of the Inlet, the surface temperature in July being around 14.5°C. The bottom temperature varies with depth, but in the deepest parts is approximately 8.5°C. There is a colder layer of water below the surface in some places, and under that, at between ten to twenty meters, a layer as warm or warmer than the surface. Below that level the temperature decreases gradually and regularly. Fresh water flows into the Inlet from several small rivers, besides the Ain, which drains three lakes, and the salinity is low. The surface salinity is not as low as in Indian Arm, Bute Inlet, or Pendrell Sound, but the bottom salinity of 22.4-23.25 °/oo is the lowest encountered in any region studied in the survey. As in Masset Sound the tidal currents are strong. The water is very well oxygenated, as there is not less than 71% oxygen in the deepest places and up to 96% at the bottom in the shallower ones.

The material from four stations collected between July 20 and 25, 1953 was available for examination. One station was in

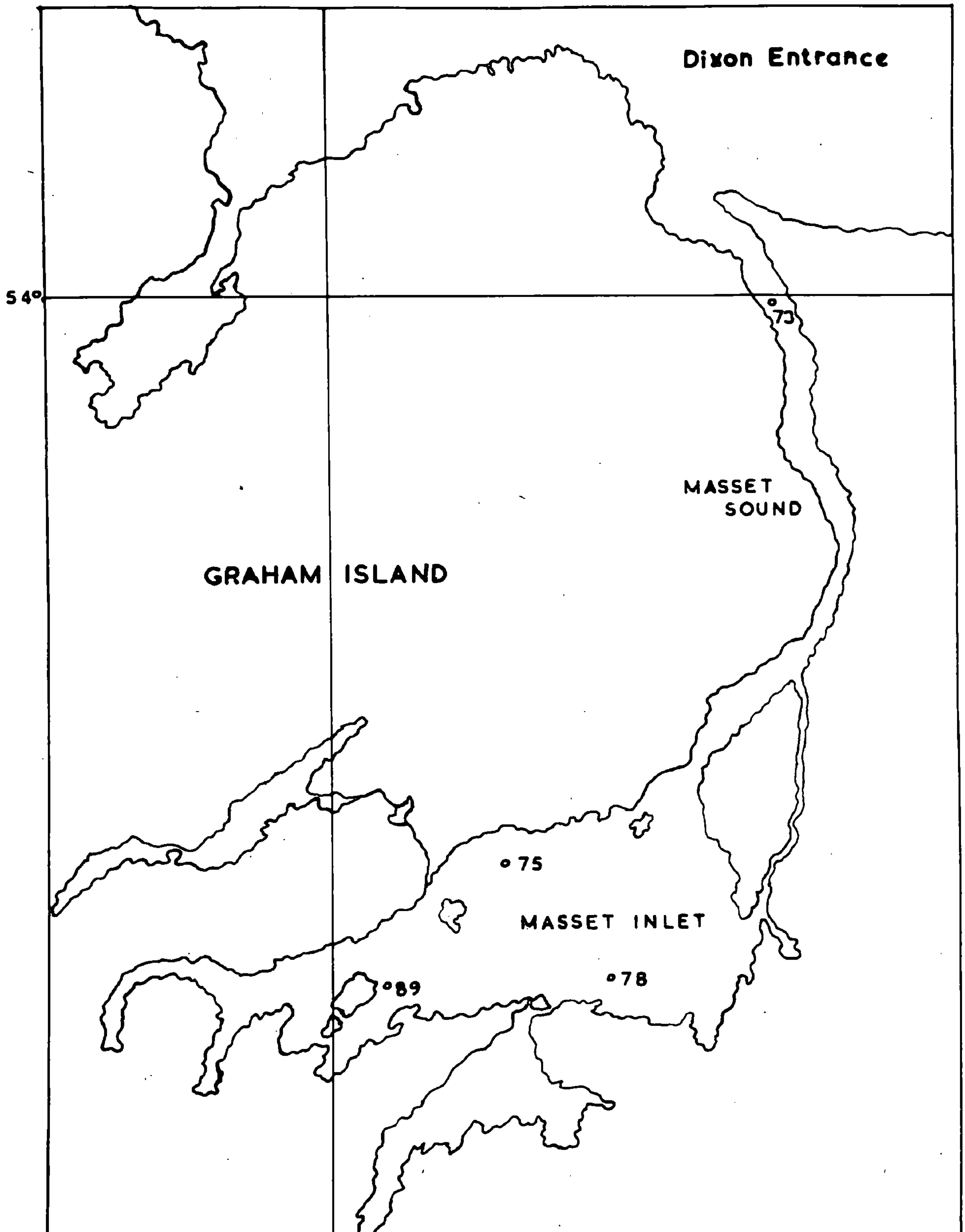
Masset Sound, and three were in widely separated regions in Masset Inlet.

No chaetognaths were taken at the single station near the entrance of Masset Sound where the depth was only fifteen meters. This does not mean that none was present anywhere in the Sound, but since chaetognaths were also absent along the coastal waters of Dixon Entrance, one may conclude that in July, there probably were no chaetognaths in the shallow, warm parts of the Sound.

In Masset Inlet S.elegans only was present, but it occurred in great abundance and in all sizes and maturity stages. Off the shoals at the eastern side a swarm of extremely small individuals was encountered. In the one haul there were 1201 specimens, mostly much under five millimeters in length. On the northern side of the Inlet, slightly larger specimens were fairly abundant, while at station 89, near the deepest part, there were hundreds of very large, opaque individuals. Fifty-seven percent of these animals measured over 20 millimeters, and more were close to 30 millimeters than to 20. Fifty-five of the 490 specimens taken in the one haul were mature and four others were maturing. For average size these were the largest specimens of S.elegans taken anywhere, though there were a few almost as large in Saanich Inlet, and one extra large individual in Dixon Entrance measured thirty-five millimeters. Nine hauls were made at this same Masset station at three-hour intervals over a period of twenty-four hours. In only one were the specimens counted, but the other samples were inspected and found to contain approximately the same number of very large, opaque specimens as the sample counted, indicating that the large S.elegans were residents in the area and not a passing swarm.

The abundance of S.elegans in Masset Sound poses several problems. Evidently the very young of the species are not repelled by high temperatures, since they were present in unusually large numbers where the temperature ranged from 14.6°C at the surface to 12.3°C at the bottom. Neither is cold water a barrier to the very small ones, since a large number of them were also found in Queen Charlotte Sound where the temperature ranged between 11°C to 8°C from top to bottom. The high oxygen content of the water in Masset may offset seemingly unfavorable high temperatures. However, Davis (1950) found that in Florida waters immature specimens of Sagitta were sometimes obtained in places where one would never find adults. He thought that it was probable that the eggs had been carried by currents to less favorable regions, where the young are either killed in time or are retarded in their development.

The opaqueness and size of the large individuals at station 89 would suggest that they were a colder water form of S.elegans, but the temperature at the bottom in July was around 8.5°C, corresponding to the highest bottom temperature in places where only a few stragglers occurred in Dixon Entrance. Perhaps S.elegans is tolerant of the warm temperatures during part of the year, in cases where it is impossible to move to colder regions. E.hamata is completely absent from the warmer regions.



MAP VIII. MASSET SOUND AND INLET - STATIONS

Position	Station	Hauls per Sta.	Depth in Meters	Sagitta elegans Numbers & Maturity		Size in mm.
Inlet E	78	1	34	Immature	1201	1.5 - 18
↓	75	1	30	Immature	156	3 - 17
W	89	1	75	Mature	55	21 - 30
				Maturing	4	23 - 30
				Immature	431	2 - 29
		Totals		Mature	55	)
				Maturing	4	) 1847
				Immature	1788	)

Table 10 - MASSET SOUND AND INLET Distribution of Chaetognaths (No chaetognaths taken in Masset Sound).

Cruise 53/6 ; July 20-24, 1953 ; C.G.M.V.Cancolim II ; Four stations, four hauls.

As is clearly shown in considering the problem of presence and distribution of the chaetognaths in Masset Inlet, it is very difficult, when specimens have been collected at one season only and by vertical hauls, even to try to suggest possible reasons for the apparent distribution.

XI WEST COAST QUEEN CHARLOTTE ISLANDS

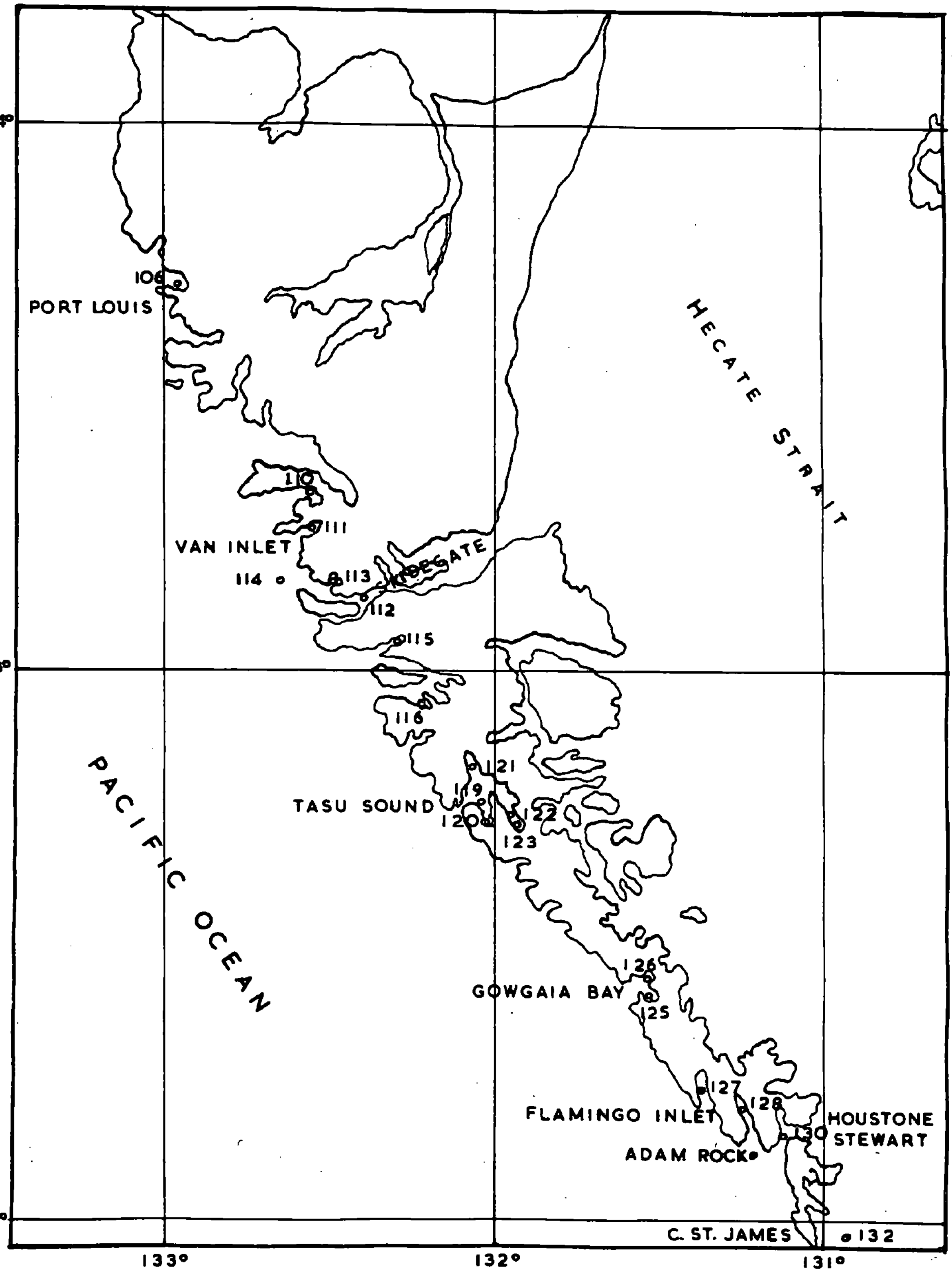
Map IX; Table 11

The Queen Charlotte Islands are a compact one hundred and fifty-five mile long archipelago of islands approximately fifty miles off the coast of British Columbia. The three principal islands are Graham, the largest and northernmost, Moresby in the center, and much smaller Kunghit at the south. Two narrow channels separate these islands, Skidegate between Graham and Moresby, and Houston Stewart between Moresby and Kunghit. On the east is Hecate Strait, and thirty-five to forty-six miles across Dixon Entrance on the north are the southern islands of Alaska. The edge of the continental shelf is only one to two miles off the west coast of the group. The twenty-two hauls made along the west coast between August 5 and 9 in 1953 were mostly located in the numerous bays and inlets of that deeply serrated coastline, none having been made beyond the continental shelf.

In most of the bays and inlets there were no chaetognaths, but Van and Tasu Inlets were exceptions. In the one haul in Van Inlet, S.elegans was not only exceptionally abundant, though all specimens were unusually small, but the proportion of mature and maturing individuals to immatures was much higher than in any other haul made anywhere in any of the areas studied. Of the 805 animals obtained, 15% were mature, 19% maturing, and 66% were immature. At this station there was a wide range of temperature from a high of 15°C at the surface to 7°C at the bottom. The water was somewhat less saline than the surface waters of the open Pacific.

Similar oceanographic conditions prevailed in Tasu Inlet, where five stations were occupied. S.elegans was again abundant, though fewer specimens were taken in each haul and none was mature. One small immature E.hamata was also found in the inlet.

Two off-shore hauls of unusual interest were made at station 114 off Skidegate Narrows and at station 132 off Cape St. James. At both of these stations, and also at station 130 in Houston Stewart Channel, the oceanic S.lyra was found. The specimens at 114 and 130 were rather small and immature, but the three taken off Cape St. James were larger and two were maturing. These had rod-like ovaries and some spermatocytes could be seen in the tails. Since this species, like S.decipiens, is a deep sea form, it was not surprising to find S.lyra near the continental shelf. Though Dr. Huntsman found it in association with S.elegans in one haul only in eastern Canadian waters, in all three hauls in which S.lyra was taken in western waters, S.elegans was also present, as was E.hamata except in the shallow haul in Houston Stewart Channel.



Map IX. QUEEN CHARLOTTE ISLANDS - Stations along west coast

Position	Station	Hauls per Sta.	Depth in Meters	*Sagitta elegans* Numbers & Maturity	*Sagitta elegans* Size in mm.	*Eukrohnia hamata* Numbers & Maturity	*Eukrohnia hamata* Size in mm.	*Sagitta lyra* Numbers & Maturity	*Sagitta lyra* Size in mm.
Port Louis	106	1	26	Immature 1	3.5	-		-	
Van Inlet	111	1	119	Mature 118 Maturing 152 Immature 535	17 - 23 15 - 19.5 2 - 18	-		-	
Offshore Skidegate	114	1	164	Immature 12	5 - 19.5	Immature 5	6 - 14.5	Immature 2	9.5 - 7
Tasu Sound	121	1	36	Immature 3	5 - 6.5	-		-	
Tasu Sound	119	1	175	Maturing 11 Immature 130	15 - 20 5 - 18	Immature 1	9.5	-	
Tasu Sound	120	1	54	Immature 12	5 - 12	-		-	
Tasu Sound	122	1	104	Maturing 2 Immature 25	18 - 19 5 - 18	-		-	
Tasu Sound	123	1	30	Immature 6	5 - 8	-		-	
Gowgaia Bay	125	1	36			Immature 1	19	-	
Flamingo Inlet	127	1	50	Immature 2	13 - 14.5	-		-	
Adam Rock	-	1	120	Immature 3	8.5 - 13.5	-		-	
Houston Stewart	130	1	41	Immature 3	6.5 - 7	-		Immature 1	6.5
Off Cape St.James	132	1	205	Maturing 2 Immature 49	18 7.5 - 18	Immature 67	5 - 17	Maturing 2 Immature 1	25 - 28 20

Totals 118 + 167 + 781 = 1066 Immature 74 Maturing 2 + Immat. 4 = 6

Table 11 - WEST COAST QUEEN CHARLOTTE ISLANDS Distribution of Chaetognaths

Cruise 53/6 ; August 5-9, 1953 ; C.G.M.V.Cancolim II ; Twenty stations, twenty-two hauls.

At station 132 off Cape St. James, where three of the six specimens of S.lyra were obtained, E.hamata surpassed S.elegans in numbers, as it did also at the outer channel station in Dixon Entrance. This fact, along with the absence of S.elegans from so many of the coastal hauls on the west coast of the Queen Charlotte Islands, and the presence of S.decipiens in two equally exposed regions, seems to be conclusive evidence that the region of the continental shelf is the outer limit for S.elegans in western Canada, as it is elsewhere, and the inner boundary for exclusively oceanic forms, as well as the beginning of the region most favorable to E.hamata, which was found only in small numbers in the inland areas.

12. EVALUATION OF THE DATA

The present investigation serves as a basic over-all survey of the species of chaetognaths found in the area and of their general distribution. The missing parts of the picture suggest many interesting problems for future research. Questions about the life histories, breeding seasons, and abundance at different seasons or from year to year arise. One also is curious as to what facts would appear if some of the other areas were sampled, including waters beyond the continental shelf.

Considering the subject of chaetognaths as indicators of currents, all that can be said at this time is that a relative abundance of S.elegans along with a few E.hamata indicates mixed coastal waters. E.hamata in abundance together with S.elegans in diminishing numbers suggests the approach of the outer limits of the mixed waters. Should S.lyra or S.decipiens be obtained, the presence of oceanic water is indicated.

13. SUMMARY

1. A study of the chaetognaths of the coastal waters of western Canada was made to discover what species were present and to determine their distribution. Samples collected during the summers of 1953 and 1954 by the Institute of Oceanography of the University of British Columbia were available from eleven representative regions along the entire coastline. Four species, representing two genera, were found to occur. These species are: Sagitta elegans, Sagitta lyra, Sagitta decipiens, and Eukrohnia hamata.

2. Sagitta elegans proved to be the most abundant and widely distributed species, occurring at least in small numbers in every area sampled. Its presence indicated mixed coastal waters, its numbers diminishing toward the edge of the continental shelf and in open areas where oceanic and coastal waters were less mixed. Oceanographic conditions varied sufficiently from area to area to make sub-specific differences apparent in some populations.

3. Eukrohnia hamata, an oceanic form, also occurring near the surface in northern regions, had penetrated most areas in small numbers, principally as a migrant carried by the cur-

rents. Warm, shallow water of low salinity prevented its entrance into two inlets, and it was missing from another where there was little circulation. *E.hamata* was found in abundance toward the edge of the continental shelf and in regions where oceanic influence was predominant.

4. *Sagitta lyra*, a species of the deep sea, was taken in very small numbers from the waters approaching the edge of the continental shelf off the west coast of the Queen Charlotte Islands. It was restricted to oceanic waters, and did not occur in any of the inland channels and inlets.

5. *Sagitta decipiens*, a deep ocean form, was taken in two regions where oceanic conditions prevailed. A few specimens were obtained in deep hauls made in Queen Charlotte Sound and at the ocean end of Dixon Entrance. Both *S.elegans* and *E.hamata* were present in large numbers in the hauls, but the stations were not far from the outer limits of *S.elegans*, and *E.hamata* was replacing *S.elegans* as the dominant species.

* * *

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