THE CHAETOGNATHA OF THE WEST COAST OF FLORIDA[1]

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Very little work has been undertaken on the Chaetognatha of the Gulf of Mexico. A short publication by Ritter-Zahony (1910) on specimens collected in the region of the Dry Tortugas, Florida, is the single paper available dealing directly with chaetognaths which might be considered as inhabitants of the Gulf. Conant (1895, 1896) has published notes and descriptions of species from the West Indies and Beaufort, North Carolina, representatives of which are found in the Gulf plankton. Davis (1949) and King (1949) have published preliminary reports on the plankton along the coast of Florida which include brief mention of the chaetognaths. Certain species of chaetognaths found in the Gulf have a cosmopolitan distribution. Reference to these species collected in other regions may be found in many papers.

The purpose of this study was to determine the species present along the west coast of Florida, their distribution, abundance and breeding seasons through an annual cycle. From previous sampling it was known that an appreciable gradient in salinity extended from the coastline to 15 miles or more offshore. It was desirable, therefore, to set up stations within this zone of variable salinity and to determine its effects on chaetognath distribution. Moreover, by attempting to locate the stations in the same relative salinity a truer comparison could be made between the populations of chaetognaths at different points along the coast.

Beginning in November, 1948 and continuing through January, 1950 plankton collections were made at monthly intervals from three well-spaced areas along the west coast. Ft. Myers Beach, Bradenton Beach and Cedar Key were selected as base points and from each of these bases three collecting stations were established approximately ½, 5 and 15 miles offshore (Fig. 1). For convenience in reference in this study, the bases are indicated by the numbers 1 (Ft. Myers Beach), 2 (Bradenton Beach) and 3 (Cedar Key), and the stations by A, B, and C from inshore to offshore, respectively. Thus, the inshore station at Ft. Myers is indicated by 1A and the offshore station at Cedar Key by 3C. These stations were all located on the inner border of the continental shelf which on the west coast of

[1] I am indebted to the University of Florida for providing funds which made this work possible. Dr. Ralph A. Morgen, Director of the Engineering and Industrial Experiment Station and Dr. C. Francis Byers, Professor of Biology, cooperated in the organization of this project. Mr. J. M. Thomson, Research Officer, Fisheries Research Station, Dunwich, Queensland, Australia, sent me identified specimens of chaetognaths taken from Australian waters. Dr. J. H. Fraser, Marine Laboratory, Aberdeen, Scotland, examined a number of specimens sent to him for identification and offered several useful suggestions. Dr. Fenner A. Chase, Jr., Curator, Division of Marine Invertebrates, United States National Museum, allowed me to work in the museum and to examine the identified chaetognaths stored there. Mr. E. D. McRae aided in the collection of the samples. I am grateful to Miss Esther Coogle, staff artist, for the careful drawings in this paper.

Part of the cost of publication was furnished by the University of Florida.

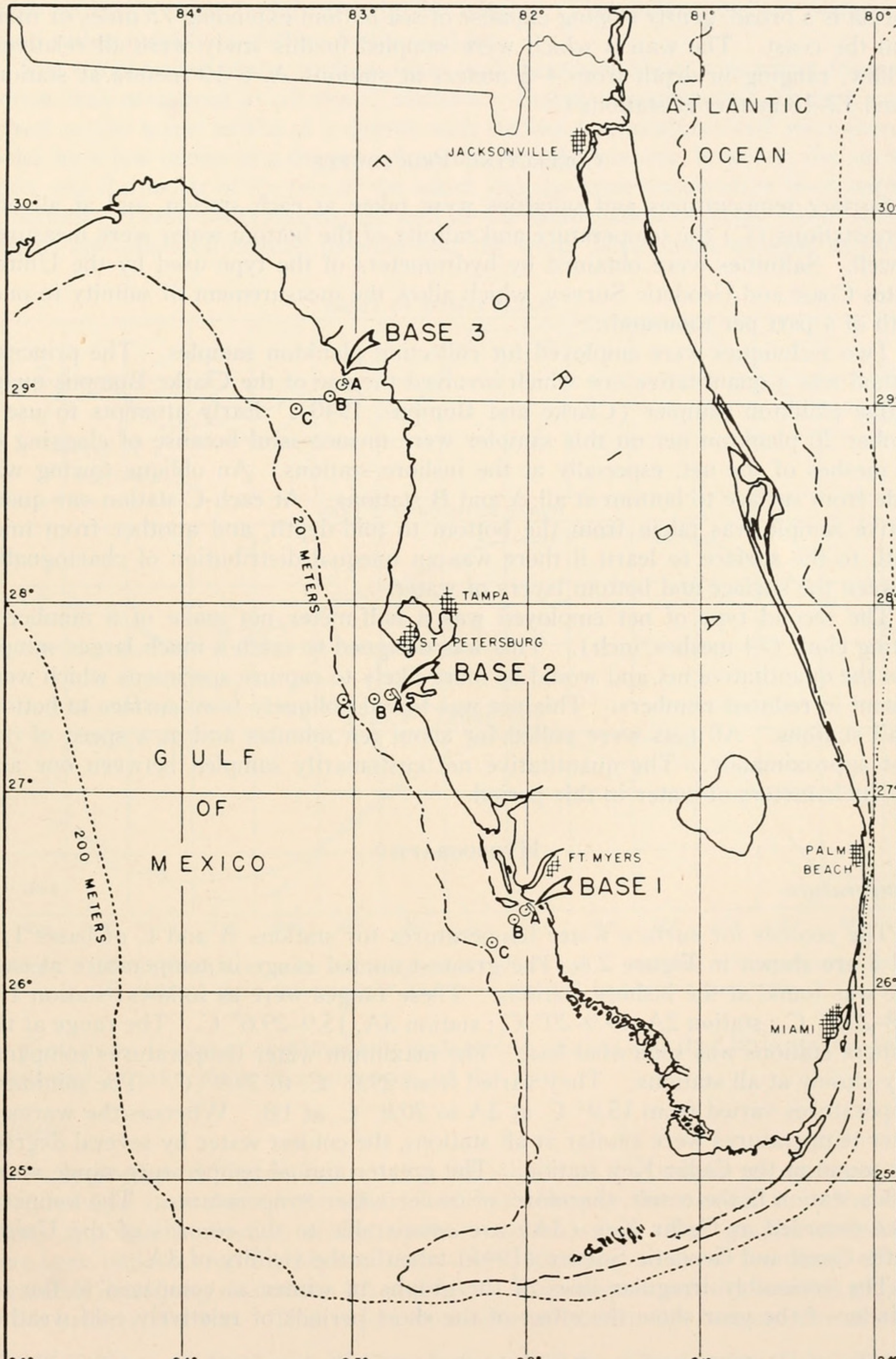

FIGURE 1. Map of Florida with the bases and stations on the west coast indicated.

Florida is a broad, gently sloping expanse of sea bottom extending 75 miles or more from the coast. The waters which were sampled in this study were all relatively shallow, ranging in depth from 4–5 meters at stations A, 6–10 meters at stations B and 12–18 meters at stations C.

Collecting Procedures

Surface temperatures and salinities were taken at each station, and at all offshore stations (C) the temperature and salinity of the bottom water were measured as well. Salinities were obtained by hydrometers of the type used by the United States Coast and Geodetic Survey, which allow the measurement of salinity to one-tenth of a part per thousand.

Two techniques were employed for collecting plankton samples. The principal method was a quantitative one which involved the use of the Clarke-Bumpus quantitative plankton sampler (Clarke and Bumpus, 1940). Early attempts to use a number 20 plankton net on this sampler were unsuccessful because of clogging of the meshes of the net, especially at the inshore stations. An oblique towing was made from surface to bottom at all A and B stations. At each C station one quantitative sample was taken from the bottom to mid-depth, and another from mid-depth to the surface to learn if there was an unequal distribution of chaetognaths between the surface and bottom layers of water.

The second type of net employed was a half-meter net made of a number 6 bolting cloth (74 meshes/inch). This was designed to catch a much larger sample than the quantitative net and would be more likely to capture specimens which were present in reduced numbers. This net was towed obliquely from surface to bottom at all stations. All nets were pulled for about ten minutes and at a speed of one knot approximately. The quantitative net customarily sampled between one and two cubic meters of water in this period.

Hydrography

Temperature

The records for surface water temperatures for stations A and C of bases 1, 2 and 3 are shown in Figure 2.[2] The greatest annual range in temperature at each base was found at the inshore stations. These ranges were as follows: station 1A, 19.8–29.7° C.; station 2A, 19.9–29° C.; station 3A, 15.9–29.6° C. The range at the offshore stations was somewhat less. The maximum water temperatures compared very closely at all stations. They varied from 29.0° C. to 29.9° C. The minimum temperatures varied from 15.9° C. at 3A to 20.8° C. at 1B. Whereas the warmest water temperatures were similar at all stations, the coldest water by several degrees was found at the Cedar Key station. The greater annual temperature range noted at this station is the result, therefore, of cooler water temperatures. The temperatures recorded at Cedar Key (3A) are comparable to the records of the United States Coast and Geodetic Survey (1944) taken in the vicinity of 3A.

The noticeably irregular lines of the graphs in winter as compared to the remainder of the year show the effect of the short periods of relatively cold weather

[2] Because of the normally small variation in temperature between the A and C stations, it was considered inadvisable to graph the figures for the B stations which were intermediate.

which normally occur in this area in the winter. The shallow inshore waters respond rather quickly to chilling by the cold air.

The temperature of the surface water and the water about one meter from the bottom was measured at all the C stations. Bottom temperatures in most cases agreed within a few tenths of a degree with surface temperatures and were usually cooler by a few tenths of a degree. In a number of instances, however, the surface water was the cooler of the two or the water was the same temperature from surface to bottom. These observations, as well as the information received from salinity records and plankton counts, indicate that the water from shore, at least as far as

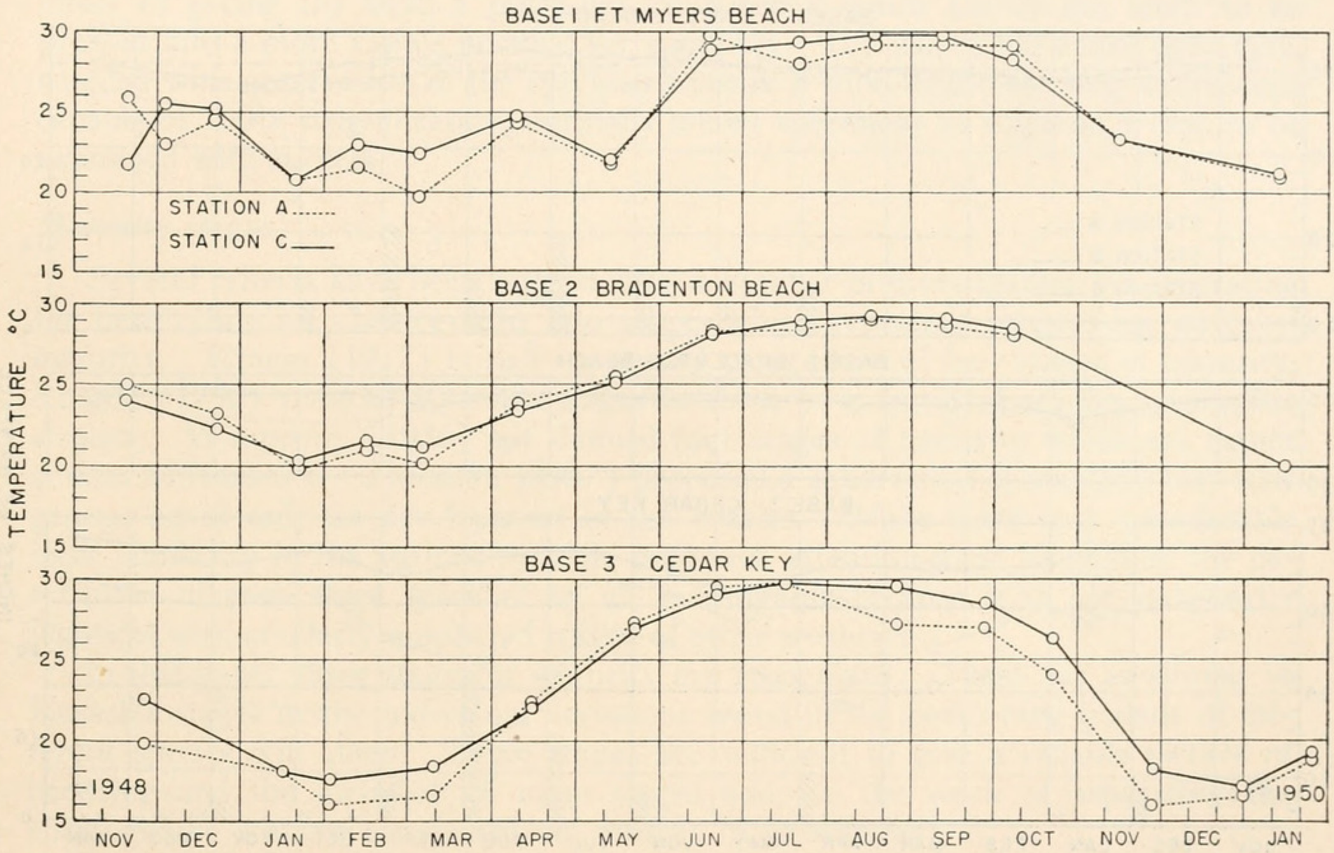

FIGURE 2. Monthly surface water temperatures at all A and C stations. Temperatures at the B stations were intermediate and were omitted to prevent confusion.

the C stations, is almost continuously undergoing mixing and that little stratification is allowed to take place at any season of the year.

Salinity

An inspection of Figure 3 shows that the salinity of the inshore waters is notably more reduced than that of the offshore stations because the run-off from the land causes appreciable dilution of the shallow coastal water. Bar graphs of rainfall have been included for Ft. Myers Beach and Cedar Key to show the direct effects of rainfall on salinity at stations 1A and 3A.[3] The range in salinity is much greater at the inshore stations. This is less noticeable at station 2A because it was rela-

[3] U. S. Dept. of Commerce, Weather Bureau. 1948–50. Climatological Data. Florida. Vol. 52, No. 13, Vol. 53 and Vol. 54.

tively farther away from the mainland drainage than either 1A or 3A. The lowest salinities were usually at 3A and were in part the result of the outflow of the neighboring Suwannee and Waccasassa Rivers in addition to the run-off from many smaller streams and marshes in that area. The highest salinities were found at stations 1C and 2C and compare closely with salinities encountered on one collecting trip which extended about 40 miles offshore in the Bradenton Beach area. The effects of dilution on salinity were noticeable at 3C.

The effects of the tide on salinity were measured at station 3A on three occasions between successive high and low tides. The salinity range in these cases was

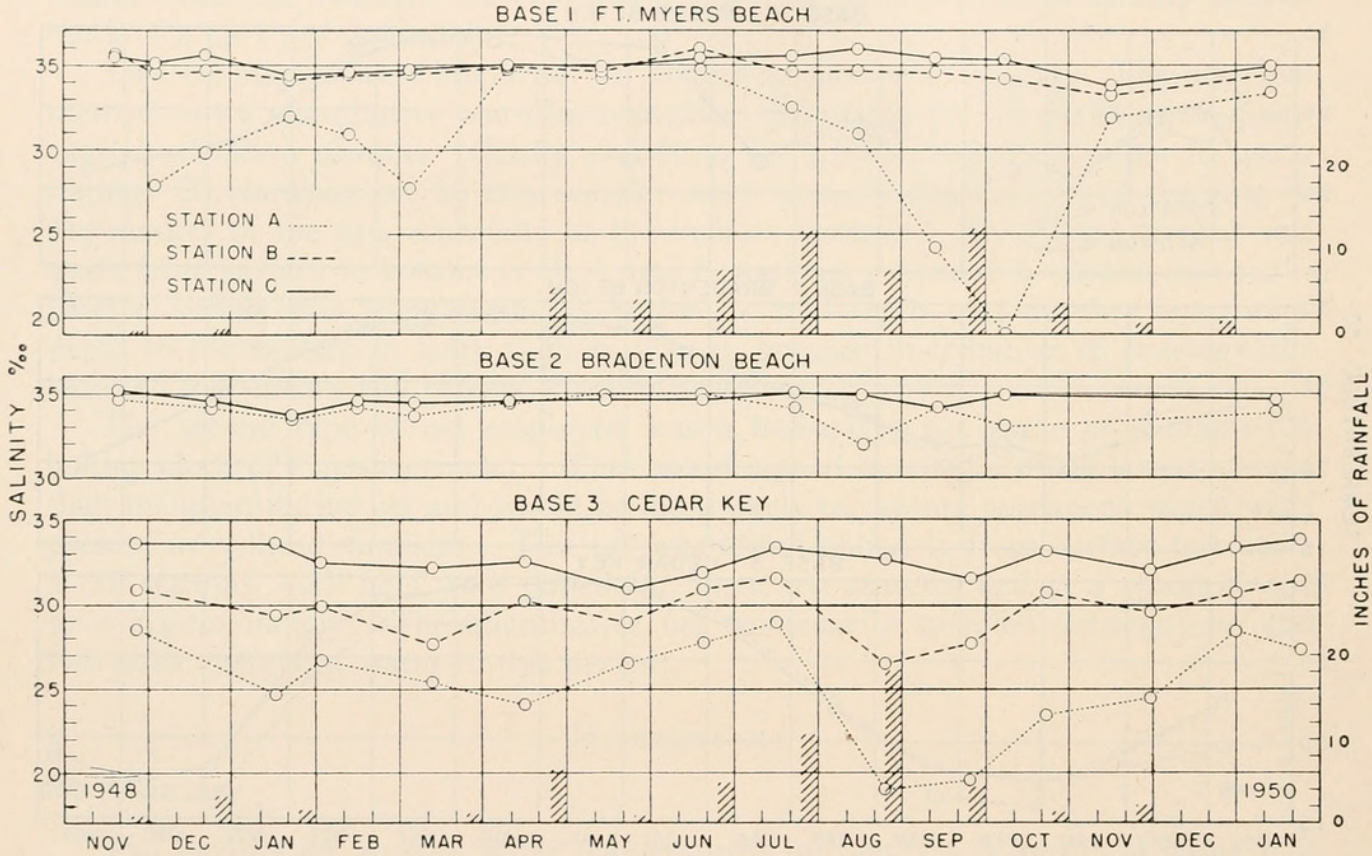

FIGURE 3. Monthly surface salinities. The bar graphs indicate total monthly rainfall at Ft. Myers and Cedar Key.

1.5‰, 1.9‰, 3.5‰. At all inshore stations these variations with the tide are undoubtedly responsible for some irregularities in the curves of salinity; however, they do not account for the more pronounced trends which are dependent to a large extent on rainfall.

MEASUREMENTS AND MATURITY STAGES

Measuring and staining

All chaetognaths were measured to the nearest millimeter. Measurements of length were made exclusive of the caudal fin. In order to see in detail certain features of the anatomy, especially the corona and gonads, it is frenquently necessary to stain the specimens. A convenient stain for this purpose is a one per cent solution of methylene blue in which the specimen need be immersed only a few minutes (Thomson, 1947). A more permanent stain which is effective for the ovaries and testes is alum carmine. The gonads are readily visible in specimens which have been left in a weak solution of this stain for several hours or overnight. If the tissues become too deeply stained, they may be de-stained rapidly by immersing the specimen in a few milliliters of water to which has been added a drop of hydrochloric acid.

It was found that by placing a chaetognath in a 2 or 3 per cent solution of iodine and potassium iodide for a few minutes, its teeth and hooks, ordinarily stain resistant, became slightly stained. This is an aid in counting the teeth when the chaetognath is held against a white background. The iodine, moreover, has the effect of giving the flesh a putty-like consistency which allows the teeth to be pressed into a more visible position for counting. The use of the above technique, coupled with observation of the specimens under a wide-field dissecting microscope capable of 100 × magnification, normally allows specimens as small as 5 mm. to be examined with success.

Maturity stages

Several criteria have been suggested by a number of investigators for separating the hermaphroditic chaetognaths into stages which represent progressive states of maturity. Kramp (1917) initially proposed recognition of four stages of maturity. Russell (1932) reduced Kramp's stages to three as a result of studies on *Sagitta elegans*. Wimpenny (1936) has defined four stages of maturity which are rather similar to Russell's. Thomson (1947) proposed a subdivision of maturity into four groups based only on development of the ovaries. While there is a considerable basic similarity in the various systems proposed, attention must be paid to the description of each stage specified by an investigator because it is not necessarily identical with similarly numbered stages of other workers.

In this paper three stages of maturity are recognized. These are as similar to Russell's stages as the individual variations found in the developing gonads of different species will allow. Three stages are sufficient to give a reliable picture of breeding and the inclusion of more stages adds to the work of separating the chaetognaths without commensurate returns in information.

In this problem either the entire sample or a fraction, usually containing 30–40 chaetognaths, was taken from the collection made at each station. All the specimens selected were measured, stained and graded into maturity stages. Because a very appreciable difference may be observed in the state of maturity for any given body length, it is believed that more valid conclusions may be reached by this procedure than by comparing the length and stage of maturity from a limited number of specimens and assuming that the remainder of the sample can be divided into maturity stages on the basis of length measurements alone.

The stages of maturity recognized in this study are:

Stage I. Immature chaetognaths which show no clusters of maturing sperm cells or spermatozoa in the tail cavity. Ovaries small or indistinct.

Stage II. Clusters of sperm cells in tail cavity. Ovaries show signs of growth. No enlarged eggs present at this stage.

Stage III. Ovaries have increased in length and some of the individual eggs have increased appreciably in size.

There is a considerable difference in the shape and size of the ovaries and in the size of the mature ova. In the case of two of the species collected, *Sagitta hispida* and *S. helenae,* the lengthening of the ovary was pronounced in the mature forms, whereas the increase in size of the individual eggs was gradual, the eggs never

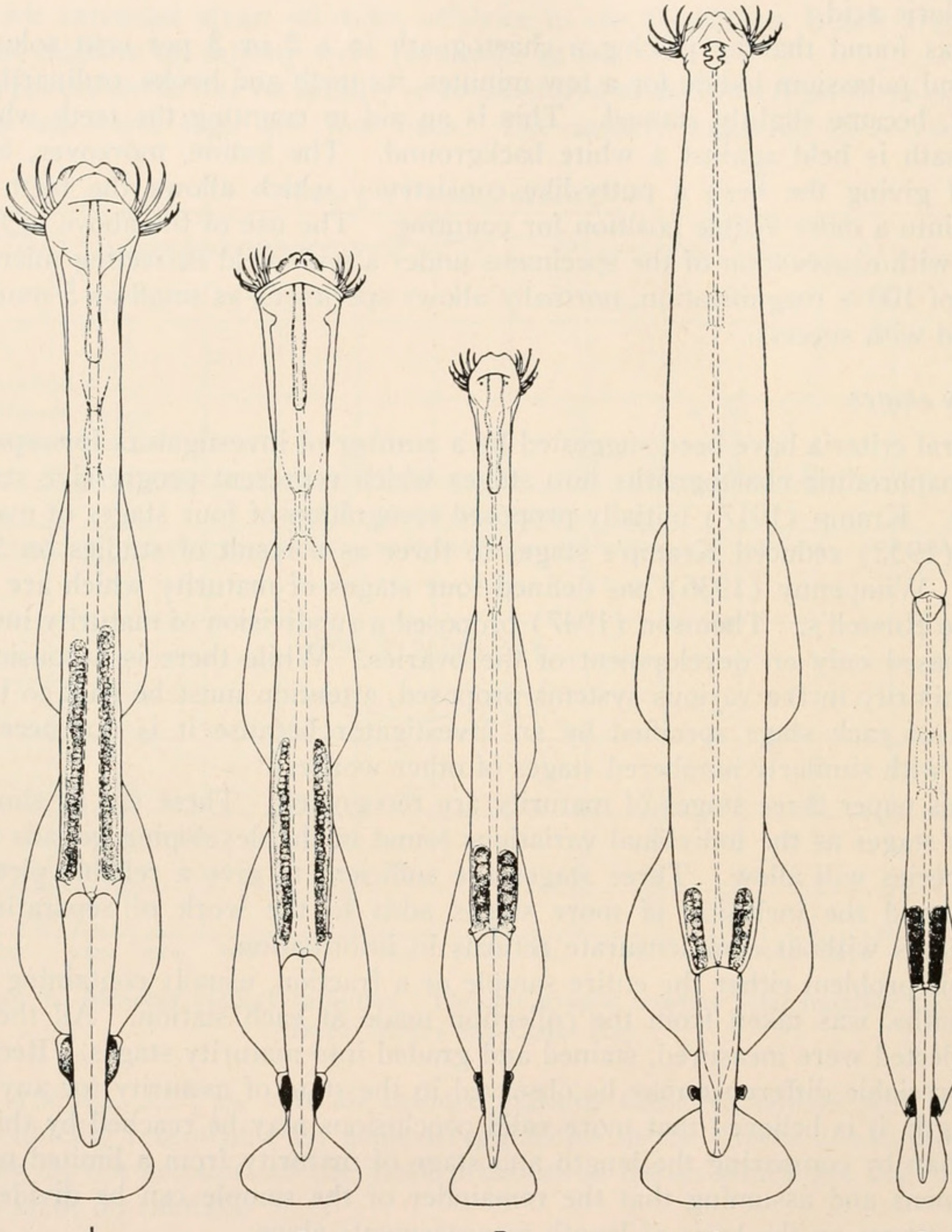

FIGURE 4. The species of chaetognaths collected along the west coast of Florida. 1. *S. hispida* 12 ×; 2. *S. helenae* 6 ×; 3. *S. tenuis* 12 ×; 4. *S. enflata* 6 ×; 5. *K. pacifica* 12 ×.

becoming very large. It was therefore decided to define the beginning of Stage III for these species as that point at which the lengthening ovary reached as far forward as the posterior end of the anterior fin. In the remaining species collected the ovaries never extended very far forward in the body cavity, but the size of the developing eggs was more evident and this was the criterion used to define Stage III as indicated above.

The differences in the details of the development of the gonads of the various species of chaetognaths are very noticeable. Not only are there differences in rate of development and size of the ovaries, but in the case of *S. enflata,* for example, the sperm balls which normally circulate freely in the tail cavity become concentrated in two packed masses at the extremity of the tail segment.

West Coast Chaetognaths

List of species. Two genera and five species of chaetognaths were collected from the west coast of Florida during the course of this investigation. These were: *Sagitta hispida* Conant, 1895; *Sagitta helenae* Ritter-Zahony, 1910; *Sagitta tenuis* Conant, 1896; *Sagitta enflata* Grassi, 1881; *Krohnitta pacifica* (Aida), 1897.

Sagitta hispida Conant (Fig. 4)

Sagitta hispida Conant, 1895, p. 290, 1896, p. 214; Fowler, 1906, p. 58; Michael, 1911, p. 27, 1919, p. 239; Burfield and Harvey, 1926, p. 96.

Sagitta robusta Ritter-Zahony, 1910, p. 136.

Description. S. hispida was originally but incompletely described by Conant (1895) from specimens obtained at Beaufort, North Carolina. This species has

Table I

Measurements of S. hispida from the west coast of Florida

Length mm.	Tail segment %	Hooks	Anterior teeth	Posterior teeth
4–5	26–27	6–8	4–6	10–11
6–7	27–28	7–9	5–6	7–10
8–9	26–29	7–8	6–9	10–12
10–11	26–29	7–8	6–9	10–12
12–13	26	8	7	10

been mis-identified on more than one occasion in the literature. Aida (1897) reported it from the harbor of Misaki in Japan. Tokioka (1939), who has studied the chaetognath fauna of Japan extensively, synonymizes *S. hispida* Aida with *S. robusta* Doncaster. Burfield and Harvey (1926) reported *S. hispida* from the Indian Ocean but their statement that the posterior fins do not extend to the seminal vesicles and that there is slightly more fin on the trunk than on the tail is not in agreement with Conant's figure or my data.

There are three specimens of *S. hispida* in the United States National Museum, which were deposited there in 1896 by F. S. Conant (Cat. No. 4984).[4] The dental formulae could not be determined without damaging these specimens, all of which were not in good condition when examined; however, the outline of the body, the position and shape of the fins and the seminal vesicles could be seen clearly on one, and these features agreed with Conant's (1895) figure and description for this

[4] Through the courtesy of Dr. Fenner A. Chase, Jr., Curator, Division of Marine Invertebrates, I was allowed to examine these specimens.

Table II

Measurements of S. hispida

Length mm.	Tail segment %	Hooks	Anterior teeth	Posterior teeth
Three specimens from Beaufort Inlet, N. C.[5]				
5	29	7	4	8
7	29	6	6	9
8	27	6	6	9
Data from Conant, 1895, Beaufort, N. C.				
7–11	33	8–9	4–5	8–15

Table III

The occurrence of chaetognaths at Base 1

Figures represent numbers per cubic meter

Species at Stations A, B, C, C′*

Date	*S. hispida*				*S. helenae*				*S. tenuis*				*S. enflata*				*K. pacifica*			
	A	B	C	C′	A	B	C	C′	A	B	C	C′	A	B	C	C′	A	B	C	C′
1948																				
19 Nov.	111	0	–	–	0	48	–	–	40	11	–	–	7	3	–	–	3	22	–	–
22 Dec.	10	0	0	0	0	48	6	7	10	28	13	41	0	34	83	45	1	11	6	0
1949																				
21 Jan.	2	99	158	48	0	4	4	3	2	106	6	8	0	0	19	20	0	2	3	0
12 Feb.	6	49	0	0	0	1	47	44	0	19	6	19	0	1	28	19	0	2	0	2
4 Mar.	41	15	0	0	0	0	45	36	41	37	7	25	0	0	24	67	0	0	3	0
9 Apr.	78	53	0	0	0	0	53	100	7	117	10	7	0	11	13	4	0	0	0	0
13 May	197	33	0	0	0	0	96	116	0	2	24	0	0	0	28	19	0	0	5	5
18 June	23	68	0	0	0	0	325	197	0	5	8	9	0	0	17	17	0	0	0	0
21 July	52	18	0	0	0	0	32	20	0	0	0	0	0	0	0	1	0	0	0	0
17 Aug.	41	73	–	0	0	0	–	25	0	0	–	0	0	0	–	0	0	0	0	0
12 Sept.	141	77	44	56	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7 Oct.	46	44	0	0	0	0	34	30	0	0	0	0	0	0	0	3	0	0	0	0
15 Nov.	130	35	0	–	0	17	31	0	4	0	0	–	0	78	6	–	0	28	0	–

* C net towed from 0 to 8 meters, C′ net towed from 8 meters to bottom. – Indicates absence of sample at that station.

species. Conant's use of a small specimen with the hood covering the head gives the impression that the head is distinctly narrower than it appears when the hooks are extended and the hood drawn back. As indicated in the table of measurements, a few specimens of *S. hispida* were secured from the entrance to Beaufort Harbor, the type locality.[5] These are in essential agreement with Conant's specimens and with the material which has been collected from the west coast of Florida.

[5] Specimens supplied through the courtesy of Dr. W. H. Sutcliffe, Jr., Duke Marine Laboratory, Beaufort, N. C.

S. hispida is a smaller than average chaetognath. The size at maturity ranges between 5 and 12 mm., 8 mm. being common. The body is rigid, collarette conspicuous, corona elongate, extending from a point anterior to the eyes well down on the body, but not reaching as far as the ventral ganglion. The fins are completely supplied with rays. The posterior fin touches the seminal vesicles in mature specimens. The number of anterior teeth is variable, ranging from 4–6 in small forms to as many as 9 in the larger specimens. These teeth are held flat against the head, a feature which in addition to the smaller number allows this species to be distinguished from *S. helenae*.

TABLE IV

The occurrence of chaetognaths at Base 2

Figures represent numbers per cubic meter

Species at Stations A, B, C, C′*

Date	*S. hispida*				*S. helenae*				*S. tenuis*				*S. enflata*				*K. pacifica*			
	A	B	C	C′	A	B	C	C′	A	B	C	C′	A	B	C	C′	A	B	C	C′
1948																				
20 Nov.	–	18	0	–	–	11	77	0	–	6	11	–	–	0	23	–	–	0	11	–
23 Dec.	–	22	0	0	–	1	26	3	–	1	18	16	–	0	25	13	–	0	8	1
1949																				
22 Jan.	15	0	0	0	0	15	4	9	7	4	3	9	0	4	9	88	0	0	0	2
13 Feb.	57	11	0	0	0	0	15	28	4	0	12	34	0	4	91	333	0	0	0	0
5 Mar.	33	0	0	0	0	0	11	7	14	0	0	0	0	0	8	32	0	0	0	0
10 Apr.	12	27	0	0	0	10	11	8	12	14	7	26	0	0	2	11	0	12	0	0
14 May	45	15	0	0	0	5	4	14	5	9	0	1	0	0	4	10	0	0	0	0
19 June	46	7	0	0	0	18	46	75	0	0	5	13	0	0	2	8	0	0	0	0
22 July	9	24	0	0	0	0	23	0	0	6	0	0	0	0	0	0	0	0	0	0
16 Aug.	54	0	0	0	0	58	50	25	0	2	0	0	0	0	0	0	0	0	0	4
13 Sept.	112	0	0	0	0	15	45	29	4	3	3	7	0	0	0	2	0	0	3	2
7 Oct.	29	17	21	69	0	2	0	19	6	2	0	0	0	0	2	0	0	8	1	19
1950																				
Jan.	49	4	0	–	0	2	32	–	4	3	11	–	0	3	9	–	0	1	1	–

* C net towed from 0 to 8 meters, C′ net towed from 8 meters to bottom. – Indicates absence of sample at that station.

Distribution. This species was taken consistently at all the A stations. A comparison of Tables I, II, III and Figure 3 shows the direct relationship of this species with the shallow, less saline coastal water. No immediate connection could be seen, however, between the month to month fluctuation of salinity at any one station and the appearance or disappearance of *S. hispida* at that station. Moreover, despite the similarities in the salinity at stations 2A and 2C, this species was almost always abundant at the inshore station (2A) and with one exception was never taken at the offshore station (2C). This suggests that some factors in addition to salinity are operating to control the distribution of chaetognaths in this area. It does not appear likely that temperature exerts any appreciable effect; for example, compare the similar temperatures at 2A and 2C (Fig. 2).

In addition to its occurrence at the regular stations, *S. hispida* was collected just off the tip of Cape Sable, August, 1949; from a point midway along the Florida Keys (Bow Channel, Sugarloaf Key) January, 1947; a channel one mile north of Key West, June, 1946; and, in company with *S. helenae*, at a point about 12 miles northwest of Key West, July, 1946. These records further indicate its preference for inshore sea water of reduced salinity.

Breeding. In the warm waters of the Gulf, *S. hispida* breeds to some extent the year round (Table IV). There was no month in which a high percentage of

TABLE V

The occurrence of chaetognaths at Base 3

Figures represent numbers per cubic meter

Species at Stations A, B, C, C′*

Date	*S. hispida*				*S. helenae*				*S. tenuis*				*S. enflata*				*K. pacifica*			
	A	B	C	C′	A	B	C	C′	A	B	C	C′	A	B	C	C′	A	B	C	C′
1948																				
26 Nov.	–	57	0	0	–	0	21	27	–	0	8	0	–	0	3	0	–	0	0	0
Dec.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
1949																				
16 Jan.	–	–	–	0	–	–	–	80	–	–	–	0	–	–	–	88	–	–	–	0
2 Feb.	18	27	122	88	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12 Mar.	46	28	0	0	0	0	31	71	0	0	11	28	0	1	2	4	0	0	0	0
15 Apr.	52	37	0	16	0	0	10	16	4	7	24	64	0	0	0	5	0	0	0	0
22 May	223	77	0	0	0	0	53	95	0	8	1	2	0	0	3	0	0	0	0	0
19 June	481	106	14	47	0	0	14	31	0	2	20	25	0	0	0	0	0	0	0	0
15 July	53	45	15	23	0	0	0	0	0	1	15	4	0	0	2	0	0	0	0	0
24 Aug.	–	37	8	17	–	0	2	0	–	0	2	2	–	0	0	0	–	0	0	0
25 Sept.	–	160	62	24	–	0	0	0	–	0	0	0	–	0	0	0	–	0	0	0
22 Oct.	–	94	22	31	–	0	0	0	–	0	0	0	–	0	0	0	–	0	0	0
29 Nov.	21	2	–	–	0	0	–	–	3	0	–	–	0	0	–	–	0	0	–	–
31 Dec.	–	13	0	–	–	0	22	–	–	0	1	–	–	0	2	–	–	0	1	–
1950																				
Jan.	13	2	2	–	0	0	17	–	–	0	8	–	–	0	1	–	–	0	1	–

* C net towed from 0 to 8 meters, C′ net towed from 8 meters to bottom. – Indicates absence of sample at that station.

Stage I individuals were not present. In March and July, 11 per cent were mature Stage III forms. There is some evidence, judging by the increase in young as well as by the appearance of mature specimens, that reproduction increased somewhat in mid-winter and again in the spring, but no well-defined breeding season could be discerned. This is in contrast to studies which have been made in northern waters, where seasonal breeding in certain species is seen more clearly (Pierce, 1941; Clarke *et al.*, 1943).

Abundance. The numbers of *S. hispida* captured per cubic meter of water sieved are shown in Tables I, II, and III. There was a sizable increase in the population in May at all A stations and in June at 2A and 3A; however, there were

Table VI

Stages of maturity for S. hispida

Data are included from all stations at which specimens were found

Date	Stage I		Stage II		Stage III		Total
	No. spec.	%	No. spec.	%	No. spec.	%	
1948							
Nov.	62	75	17	20	4	5	83
Dec.	31	72	12	28	0	0	43
1949							
Jan.	187	91	17	8	3	1	207
Feb.	168	84	29	14	3	2	200
Mar.	42	50	33	39	9	11	84
Apr.	79	54	67	45	1	1	147
May	155	80	38	19	2	1	195
June	141	49	139	48	9	3	289
July	99	54	65	35	19	11	188
Aug.	213	78	49	18	10	4	273
Sept.	370	74	116	23	16	3	502
Oct.	156	73	50	23	8	4	214
Nov.	54	83	10	15	1	2	65
Dec.	72	95	4	5	0	0	76
1950							
Jan.	33	73	12	27	0	0	45

still numbers of young Stage I forms present during the other months of the year (Table IV) which is consistent with the evidence that breeding is continuous the year round.

A comparison may be made of the abundance of *S. elegans* over Georges Bank, off Massachusetts, during five cruises made in 1940 (Clarke *et al.*, 1943) with the number of *S. hispida* taken at three stations on the west coast for corresponding months. The maximum concentration of *S. elegans* for each cruise has been selected for comparison.

Table VII

*Comparison of catches of S. elegans from Georges Bank, Massachusetts and S. hispida from the west coast of Florida**

	January	March	April	May	June
Georges Bank 1940	26	5	11	43	112
West Coast of Florida 1949					
Station 1A	2	41	78	197	23
Station 2A	15	33	12	45	46
Station 3A	13	46	52	223	481

* Figures represent individuals per cubic meter.

With some exceptions, the numbers of individuals are higher along the west coast than they are over Georges Bank. Of course, two different species are being compared; nonetheless, the data do suggest that population increases in northern waters are not always greater than population increases for similar species in the south during the breeding season.

Sagitta helenae Ritter-Zahony (Fig. 4)

Sagitta helenae Ritter-Zahony, 1910, p. 134, 1911a, pp. 18, 1911b, p. 20; Michael, 1919, p. 239; Thomson, 1947, p. 36; Moore, 1949, p. 26.

Description. This species was described by Ritter-Zahony (1910) from specimens taken near Dry Tortugas, Florida. It is a medium sized form with rather heavy body musculature and a large number of anterior teeth. The number and arrangement of these teeth allow it to be distinguished from the very similar though smaller *S. hispida* Conant. The anterior teeth in *S. helenae* are more abundant for any given size than are the teeth in *S. hispida*. In the 6–10 mm. range the difference is apt to be two to three anterior teeth; in the larger specimens

TABLE VIII

Measurements of S. helenae from the west coast of Florida

Length mm.	Tail segment %	Hooks	Anterior teeth	Posterior teeth
6–7	25–27	6–7	8–10	7–10
8–9	26–28	6–8	9–12	9–13
10–11	25–26	7–8	11–16	11–12
12–13	24	7	15	11–12
14–15	24–25	7–8	15–16	11–14

the difference is greater, usually amounting to 6–8 more teeth on each side. The anterior teeth in *S. helenae* exhibit a very noticeable overlap a short distance back from the points. In the majority, the teeth stand out from the head and resemble, in miniature, a small curved fan.

Distribution. This was the most common chaetognath in the plankton at station 1C, 2C and on occasions at 3C. A form widely ranging along the west coast, it was customarily found in water of 34–35$^0/_{00}$. It is significant that its presence at any station was with few exceptions assurance that *S. hispida* would be absent or found there in only minor numbers (Tables I, II and III). The Cedar Key area offered the least favorable environment for this species. It was never taken there at either 3A or 3B stations and in a number of instances it was absent from 3C as well.

Further information concerning the distribution of *S. helenae* along the west coast was obtained from a number of scattered samples taken over a period of several years. Two samples taken 30 and 50 miles southwest of Bradenton Beach, October, 1949, contained *S. helenae* in some abundance. A plankton tow made 12 miles northwest of Key West in July, 1946 contained a few *S. helenae*. Other samples taken in the close vicinity of Key West and in Florida Bay contained no representatives of this species. This information strengthens the evidence that *S. helenae* will not tolerate indefinitely conditions where the salinity is several parts per thousand below normal, but will be found in high salinity water over the continental shelf along the west coast of Florida. No positive information concerning its offshore distribution in the Gulf is at present available.

Breeding. Evidence for year round breeding of *S. helenae* is seen in the abundance of Stage I individuals in every month. The general distribution of all stages during the year makes it difficult to select periods in which reproduction was accelerated. The large increase in the numbers of young individuals in May and June suggests that this was a time when breeding had increased.

TABLE IX

Stages of maturity for S. helenae

Data are included from all stations at which specimens were found

Date	Stage I		Stage II		Stage III		Total
	No. spec.	%	No. spec.	%	No. spec.	%	
1948							
Nov.	181	90	17	9	2	1	200
Dec.	108	87	15	12	1	1	124
1949							
Jan.	231	94	16	6	0	0	247
Feb.	50	62	19	23	12	15	81
Mar.	243	90	23	9	3	1	269
Apr.	53	58	33	36	5	6	91
May	315	88	41	11	2	1	358
June	155	83	27	14	6	3	188
July	21	25	50	59	14	16	85
Aug.	87	94	6	6	0	0	93
Sept.	63	67	31	33	0	0	94
Oct.	29	71	7	17	5	12	41
Nov.	148	92	13	8	0	0	161
Dec.	29	88	4	12	0	0	33
1950							
Jan.	159	73	44	21	14	6	217

Abundance. The abundance of *S. helenae* at the C stations is generally similar to the number of *S. hispida* at the A stations (Tables I, II and III). The optimum location sampled regularly was 1C with 2C next. The largest number per cubic meter found at any one time was 325 on 18 June 1949 at 1C.

Sagitta tenuis Conant (Fig. 4)

Sagitta tenuis Conant, 1896, p. 213; Fowler, 1906, p. 61; Michael, 1911, p. 72, 1919, p. 239; Germain and Joubin, 1916, p. 51. (?); John, 1933, p. 4.
Sagitta friderici Ritter-Zahony, 1911a, p. 19, 1911b, p. 21.

Description. Described by Conant in 1896 from specimens collected June, 1893, Kingston Harbor, Jamaica. Several syntypes have been deposited by him in the

United State National Museum (Cat. No. 4986). A comparison of these specimens with the ones collected on the west coast revealed that they were the same species. Again there is an inadequate description and no figure. The following data were listed in the original description:

Maximum length	Tail segment	Hooks	Anterior teeth	Posterior teeth
5.25 mm.	25 per cent approx.	7–8	4–5	7–10

The greatest discrepancy in the above figures lies in the smaller number of posterior teeth listed by Conant. This is probably not very significant in view of the very small specimens with which he had to work.

These are small slender chaetognaths. The fins are completely set with rays with posterior and caudal fins touching the seminal vesicles in mature individuals. The anterior fins reach forward to the ventral ganglion. The corona is elongate, extending from beyond the eyes more than halfway to the ventral ganglion. The seminal vesicles are slender with a rounded knob on the anterior end when mature. The posterior fins lie more on the tail segment than on the trunk. A line drawn along the edges of each group of anterior teeth would meet medially at an acute to right angle. The collarette is small, evident at the junction of the head and body. The ovaries are short, not usually extending much beyond the posterior fin. The individual eggs are few and rather large in the short ovary. *S. tenuis* can readily be separated from *S. hispida* by the shape of the seminal vesicles and the arrangement of the anterior teeth.

Ritter-Zahony (1910, p. 141) attributes characters described by Conant for *S. tenuis* to *S. bipunctata* and fails to recognize it as a valid species. Michael (1911, p. 73) recognizes *S. tenuis* as a species in good standing. On the other hand, *S. friderici* Ritter-Zahony (1911b) is almost certainly a synonym of *S. tenuis*. The description and figures of *S. friderici* are in complete accord with the specimens from the west coast of Florida, and Conant's *S. tenuis*. Ritter-Zahony obtained his collection from the neighborhood of Porto Grande, Cape Verde Islands.

TABLE X

Measurements of S. tenuis from the west coast of Florida

Length mm.	Tail segment %	Hooks	Anterior teeth	Posterior teeth
6	25	8	6	15
7	26	7–8	6–7	18–19
8	27	8	7	15

Distribution. The most widely distributed chaetognath on the west coast, it was found on occasion at every station, although somewhat less abundantly at the A stations. It also occurs on the east coast and apparently in greater numbers than on the west coast. Specimens were obtained from Salerno, and St. Augustine, Florida, and Beaufort Inlet,[6] North Carolina.

[6] Beaufort Inlet material obtained through the courtesy of Dr. W. H. Sutcliffe, Jr., Duke Marine Laboratory, Beaufort, N. C.

Breeding. This species appears to breed to some extent throughout the year. Mature forms were found in every month, with the exception of October when very few specimens were captured in any stage.

Abundance. *S. tenuis,* more than either of the two previously discussed species, shows some seasonal occurrence. It was present in numbers during winter and spring but diminished or disapppeared during the summer and early fall months. This coincides with the period of highest water temperature (Fig. 2) and possibly

TABLE XI

Stages of maturity for S. tenuis

Data are included from all stations at which specimens were found

Date	Stage I		Stage II		Stage III		Total no.
	No.	%	No.	%	No.	%	
1948							
Nov.	12	32	18	47	8	21	38
Dec.	60	58	32	31	12	11	104
1949							
Jan.	45	30	63	40	45	30	153
Feb.	20	43	14	30	13	27	47
Mar.	66	38	60	34	49	28	175
Apr.	39	35	53	47	21	18	113
May	0	0	25	58	18	42	43
June	26	51	21	41	4	8	51
July	1	4	16	64	8	32	25
Aug.	0	0	5	50	5	50	10
Sept.	2	8	15	62	7	30	24
Oct.	0	0	3	100	0	0	3
Nov.	7	33	11	52	3	15	21
Dec.	0	0	17	61	11	39	28
1950							
Jan.	3	7	15	35	25	58	43

the high water temperatures affected it adversely. Although widely distributed, it did not occur in as large numbers as did *S. hispida* and *S. helenae.*

Sagitta enflata Grassi (Fig. 4)

Sagitta enflata Grassi, 1881, p. 213; Beraneck, 1895, p. 153; Aida, 1897, p. 15; Doncaster, 1902, p. 210; Fowler, 1906, p. 8; Ritter-Zahony, 1910, p. 139, 1911a, p. 13, 1911b, p. 16; Michael, 1911, p. 28, 1919, p. 242; Bigelow, 1926, p. 334; Burfield and Harvey, 1926, p. 111; John, 1933, p. 1; Tokioka, 1939, p. 126, 1940a, p. 2, 1940b, p. 369, 1942, p. 527; Redfield and Beale, 1940, p. 472; Clarke, Pierce and Bumpus, 1943, p. 221; Thomson, 1948, p. 18, 1947, p. 11; Moore, 1949, p. 25; Davis, 1949, p. 88; King, 1949, p. 119.

Sagitta flaccida Conant, 1896, p. 213; Doncaster, 1902, p. 211.

Sagitta gardineri Doncaster, 1902, p. 212; John, 1933, p. 2.

Sagitta inflata Germain and Joubin, 1916, p. 33.

Description. *S. enflata* is a medium sized, well known and easily recognized chaetognath. The overlapping anterior teeth, the short corona situated on the head, the small knob-like seminal vesicles, together with the flaccid body are features which characterize this species.

Distribution. Along the west coast *S. enflata* occurred seldom or never at the A and B stations and was present in reduced numbers and then only at scattered intervals at 3C (Tables I, II and III). It occurred normally in the samples in which *S. helenae* was found, and if *S. helenae* were absent *S. enflata* was usually absent as well. As was the case for *S. tenuis,* it almost completely disappeared during late summer and early fall. *S. enflata* appears to have little tolerance for either low salinities or persistent high temperatures. In the tropics the ability of *S. enflata* to perform vertical migrations might remove it when necessary from the very warm surface waters. Moore (1949) states that in the Bermuda area its mean day level was 115 meters.

TABLE XII

The measurements of S. enflata from the west coast of Florida

Length mm.	Tail segment %	Hooks	Anterior teeth	Posterior teeth
8–9	15–18	8–9	5–6	8
10–11	17	8–9	5	8
12–13	16–18	8–9	6–7	11
14–15	16–17	8–9	7–9	10–13
16–17	17	8	9	14
18–19	15–17	8	7–9	13–14
20–21	15	9	11	15

S. enflata is typically an offshore species. It has a cosmopolitan distribution in all the warmer seas. Ritter-Zahony (1911b) states that its range is between 40°N and 40°S latitude. These limits appear to be generally true as far as the existence of a permanent population is concerned, although there are records of its occurrence farther north (Redfield and Beale, 1940).

Breeding. The data are too scattered to permit valid conclusions concerning the breeding season; however, the presence of Stage I forms at all seasons suggests that the period of reproduction is a long one in this area.

Abundance. Judged on a year round basis this species was fourth in abundance in the west coast area (Tables I, II and III). Usually occurring in numbers of less than 50 per cubic meter, it occasionally exceeded this figure in the winter months.

Krohnitta pacifica (Aida) (Fig. 4)

Krohnitta pacifica Tokioka, 1939, p. 135, 1940a, p. 7, 1942, p. 546; Thomson, p. 22.
Krohnia pacifica Aida, 1897, p. 19; Doncaster, 1902, p. 215; Fowler, 1906, p. 24.
Krohnitta subtilis (partim) Ritter-Zahony, 1910, p. 140, 1911a, p. 44, 1911b, p. 32.
Eukrohnia pacifica Michael, 1911, p. 76.

Description. Ritter-Zahony (1910) established the genus *Krohnitta* and synonymized *K. pacific* under *K. subtilis.* As indicated by Tokioka (1939) and

Table XIII

Stages of maturity for S. enflata

Data are included from all stations at which specimens were found

Date	Stage I		Stage II		Stage III		Total no.
	No.	%	No.	%	No.	%	
1948							
Nov.	20	76	3	12	3	12	26
Dec.	79	79	16	16	5	5	100
1949							
Jan.	119	75	20	12	20	12	159
Feb.	115	89	11	9	3	3	129
Mar.	120	74	36	22	7	4	163
Apr.	16	53	5	17	9	30	30
May	81	88	11	12	0	0	92
June	10	77	3	23	0	0	13
July	1	100	0	0	0	0	1
Aug.	2	100	0	0	0	0	2
Sept.	4	100	0	0	0	0	4
Oct.	1	50	1	50	0	0	2
Nov.	82	99	0	0	1	1	83
Dec.	42	93	3	7	0	0	45
1950							
Jan.	42	71	17	29	0	0	59

Thomson (1947) these are separate and clearly defined species. *K. pacifica* is a shorter, broader form with a relatively large ovary extending beyond the border of the posterior fin when mature. The ovary in *K. subtilis* is small, hardly as long as the width of the body.

Distribution. The occurrence of *K. pacifica* along the west coast was sporadic. It was found in some of the fall and winter samples at 1B, 1C and 2B, 2C in small numbers (Tables I, II and III). Only two specimens were taken in the quantitative sampler in the Cedar Key area. This latter region is clearly the least favorable of the three for this species.

Table XIV

Measurements of K. pacifica from the west coast of Florida

Length mm.	Tail segment %	Hooks	Teeth
5	28–29	9	11
6	27–28	8–9	12
7	30	9	12

Breeding. Not enough specimens were collected to warrant definite conclusions on the breeding of this species; however, whenever any number were taken, some of them were almost invariably mature. This strongly suggests that the breeding season for *K. pacifica* is a long one in this region. Stage I individuals were rarely recorded because their minute size (two–three mm.) made selection from the samples difficult and subject to error.

Abundance. It was clearly the least abundant of the chaetognaths collected. The maximum number encountered was 28 per cubic meter in November, 1949 at station 1B. Although it did not appear simultaneously at the Ft. Myers Beach or

TABLE XV

Stages of maturity for K. pacifica

Data are included from all stations at which specimens were found

Date	Stage I	Stage II	Stage III	Total
	No.	No.	No.	
1948				
Nov.	0	14	44	58
Dec.	0	8	3	11
1949				
Jan.	0	2	2	4
Feb.	0	0	4	4
Mar.	0	1	2	3
Apr.	2	3	3	8
May	0	0	0	0
June	0	0	0	0
July	0	1	0	1
Aug.	0	1	1	2
Sept.	0	4	3	7
Oct.	0	4	12	16
Nov.	1	8	6	15
Dec.	0	1	8	9
1950				
Jan.	0	7	8	15

Bradenton Beach stations, it was captured on 13 occasions in each area and in roughly comparable numbers.

Regeneration in Chaetognaths

An unusual phenomenon was observed in a number of specimens of *S. helenae* and *S. enflata* (26 were taken from the samples). These individuals were found to have lost their heads, together with a short section of the trunk and were in various stages of head regeneration (Fig. 5). This condition was at first attributed to accidental damage encountered in the net; however, as additional specimens were encountered in which various degrees of head regeneration could be observed, it was concluded that this was not an unusual occurrence and that the loss of this section of the body did not necessarily kill the individual. No instances of the re-growth of the tail or posterior end of the body were observed.

Upon the loss of the head the trunk tissues contract tightly together at the severed end. This gives the appearance of the tied end of a sausage casing. The head begins to form within the constricted end. The eyes appear early, followed by the mouth and finally jaws appear.

Other features which lend interest to this observation are that although many hundreds of *S. setosa* and *S. elegans* from northern latitudes were carefully inspected in other studies, no evidence of regeneration of the head was ever observed. No mention of such phenomena has been recorded in the literature reviewed.

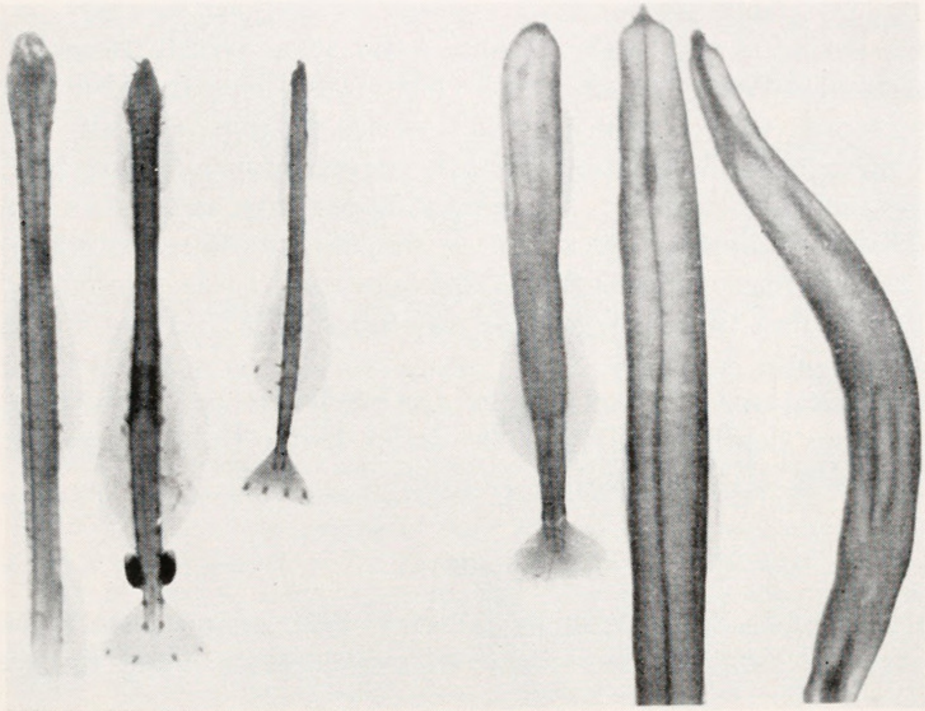

FIGURE 5. Chaetognaths showing various stages of head regeneration. The three specimens on the left are *S. helenae*. The three on the right are *S. enflata*.

DISCUSSION

A comparison of the three base areas shows a considerable similarity between Bases 1 and 2 from the point of view of occurrence and abundance of the five species. The Cedar Key area, with its reduced salinity and the predominance of *S. hispida*, showed somewhat greater differences in its chaetognath fauna from the other two.

The distribution of the chaetognaths along the coast is consistent with the hydrographic conditions operating there. Inshore, there is a very appreciable drift of water northward along the coast (United States Hydrographic Office, Current Charts, Central American Waters). Although the figures vary considerably from month to month, a rough average of 6–8 miles per day would indicate the magnitude of the movement involved. In the Bradenton Beach area this northward counter current may at times exceed 20 miles per day. The fact that the movement of water is parallel to the coast, together with the relatively mild tides in this area, allows salinity and faunal areas paralleling the coast to persist almost indefinitely. At the same time, this northward movement of water is responsible for the wide distribution of the chaetognaths within the respective areas of salinity. It was significant to find the difference in distribution between *S. hispida* on the one hand and *S.*

helenae and *S. enflata* on the other. Along the west coast of Florida the former was characteristically found in the inshore water of low salinity, whereas the two latter species were seldom taken in company with *S. hispida.* The year-round persistence of the difference in the distribution of the species substantiates the lack of lateral mixing which was also indicated by the salinity gradient found along the coast. There is reason to believe that these species might be successfully used as indication of the movement of water from offshore inward or from the inshore outward.

During the period of this study, despite a hurricane which traversed almost the length of the state on August 26–27, 1949 (Latour and Bunting 1949), no unusually high salinity records were obtained at the inshore stations, nor was there any evidence from chaetognath distribution that species occurring offshore had been swept inshore in any numbers. In fact, the reverse appears to have taken place. On 12 September, 16 days following the storm, *S. hispida* was taken at station 1C which was the first time in many months that it had appeared at this station, and *S. helenae* was absent for the first time. *S. hispida* was taken at 2C for the first time the following month.

Additional collections of chaetognaths are needed from points far out into the Gulf and at various depths to allow us to define better the offshore range of such species as *S. helenae, S. tenuis* and *K. subtilis.*

Summary

1. From November, 1948 through January, 1950 quantitative plankton collections were made at monthly intervals from nine stations along the west coast of Florida.

2. Surface water temperatures and salinities were taken at each station. The warmest water temperatures were similar at all stations but the coldest water by several degrees was found at the Cedar Key station (3A).

3. The inshore water at all stations showed reduced salinity. This was correlated with rainfall. The salinity increased from the inshore to the offshore stations.

4. Three maturity stages were described for the chaetognaths based on development of testes and ovaries.

5. The chaetognaths collected were: *S. hispida, S. helenae, S. tenuis, S. enflata, K. pacifica.* One of these, *S. hispida,* exists characteristically in dilute inshore water. *S. helenae* and *S. enflata* were normally absent at the inshore stations where *S. hispida* was abundant. They were most numerous at the C stations where the salinity of the water varied around $35^0/_{00}$. *S. tenuis* appeared to be rather tolerant of fluctuations in salinity although in the Cedar Key area, where the lowest salinities were encountered, it was noticeably scarce at the inshore stations. The catches of *K. pacifica* were too few and scattered to give a good picture of its local distribution. It was more abundant in waters of high salinity than elsewhere.

6. The data indicated that breeding was, with some fluctuations, continuous the year round.

7. *S. hispida* and *S. helenae* were found at all seasons. Increased numbers of Stage I forms appeared in the late spring and summer, resulting in an over-all increase in the population. *S. tenuis* and *S. enflata* were noticeably most abundant during the colder months.

8. A northward movement of the coastal water helps distribute the chaetognaths and apparently does not interfere seriously with the persistence of water of reduced salinity in the inshore areas.

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