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Jerry A. McLelland
Gulf Coast Research Laboratory

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OBSERVATIONS ON CHAETOGNATH DISTRIBUTIONS IN THE NORTHEASTERN GULF OF MEXICO DURING THE SUMMER OF 1974

Jerry A. McLelland
Ecology Section
Gulf Coast Research Laboratory
Ocean Springs, MS 39564

ABSTRACT: The chaetognath population was studied from zooplankton samples collected at twelve stations in the northeastern Gulf of Mexico in June 1974. Quantitative analysis of six stations revealed a large inshore population composed largely of juveniles and neritic species in the upper strata, and a progressively smaller and more evenly dispersed assemblage composed largely of oceanic, stenohaline species at stations further offshore. The high percentage of juveniles in surface samples evidenced an early-summer spawning peak for the population as a whole.

Overlying low salinity water throughout the study area was characterized by the presence of two neritic species, *Sagitta tenuis* and *S. friderici*, in surface samples, while an underlying high salinity intrusion over the continental shelf was denoted by the submerged occurrence of stenohaline species.

Fourteen species were grouped into three ecological categories denoting degrees of tolerance to environmental change: (1) neritic — *Sagitta friderici*, *S. tenuis*, *S. helenae*, *S. hispida*, (2) mixed water — *S. enflata*, *S. minima*, *S. serratodentata*, *Pterosagitta draco*, *Krohnitta pacifica*, and (3) oceanic — *S. hexaptera*, *S. bipunctata*, *K. subtilis*, *S. decipiens*, *S. lyra*.

The Chaetognatha, or arrow worms, are a small phylum of ubiquitous, mostly planktonic, marine organisms. They are known worldwide as voracious predators in the marine food chain and have become useful as hydrological indicators of current systems owing to their affinity for specific water types.

The first major publication dealing with chaetognaths in the Gulf of Mexico was that of Pierce (1951) describing the seasonal distribution and population dynamics of five species from the west coast of Florida. This study laid the groundwork for future research in Gulf coastal waters and, according to Tokioka (1955), confirmed the validity of two important Gulf species, *Sagitta hispida* and *S. tenuis*. Subsequent publications documented chaetognath occurrences in various coastal regions and in remote areas toward the center of the Gulf (Pierce 1954, 1962; Suarez-Caabro 1955; Vega-Rodriguez 1965; Kolesnikov and Alfonso 1966; Mostajo 1978; Maidana and Mostajo 1980). However, except for a limited study by Mulkana and McIlwain (1973) on seasonal occurrence at one station in Mississippi Sound, there has been little published information on the chaetognath population structure in the northeastern Gulf. This paper, the result of graduate research (McLelland 1978), provides documentation of species distribution in waters adjacent to Louisiana, Mississippi, and Alabama during June, 1974.

MATERIALS AND METHODS

Plankton samples and hydrographic data were collected in June 1974 by Gulf Coast Research Laboratory (GCRL) personnel as part of a U.S. Bureau of Land Management (BLM) baseline environmental survey of oil lease sites in the northeastern Gulf of Mexico, which was conducted by the State University System of Florida Institute of Oceanography Consortium (SUSIO).*

Twelve stations (Fig. 1) composed of six "master" stations (M10-M15) in the lease areas, two control stations (C3, C4) adjacent to the lease sites, and four alternate stations (A4-A7) were sampled from the R/V GULF RESEARCHER (Table 1). Hydrographic data were obtained using expendable bathythermographs (XBT) for temperature vs. depth and 30L hydrocast samples for stratified salinity and dissolved oxygen titration measurements (provided by SUSIO). Zooplankton samples were collected using Niskin 0.5 m, 202 μm mesh plankton nets equipped with double-trip mechanisms and General Oceanics flowmeters to simultaneously sample the surface, middepth, and bottom strata. Replicate 15-minute, stepped oblique tows were made at the master stations and one-hour tows were made at the alternate and control stations. The samples were preserved in the field with 5% buffered formalin.

In the laboratory, master station samples were repeatedly halved with a Folsom splitter until aliquots containing at least 200 chaetognaths were produced. A stereoscopic dissecting microscope equipped with an ocular micrometer was used to obtain counts, identify species, and examine specimens

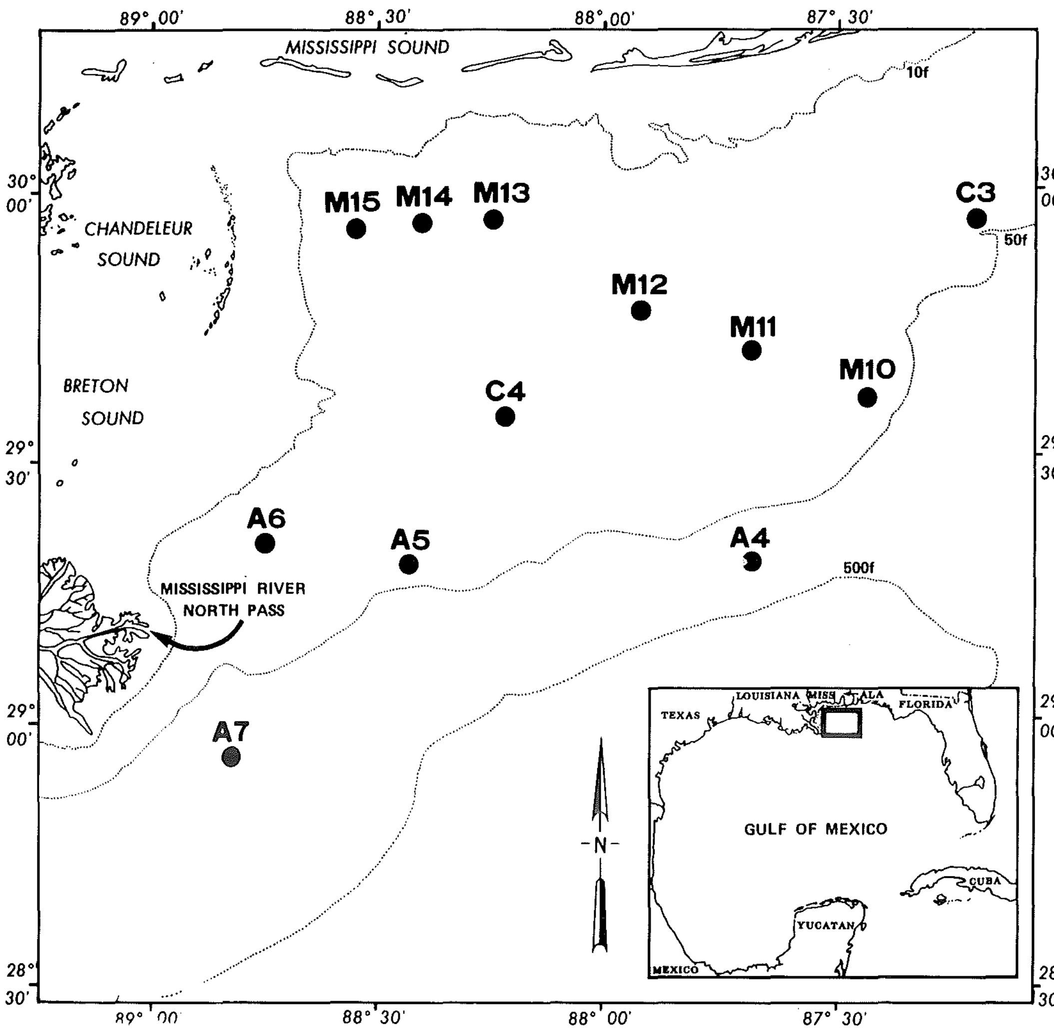

Figure 1. Station locations in the northeastern Gulf of Mexico.

for gonadal development. Two mid-day replicates from those collected at each master station sampling strata were selected for quantitative examination. The hour tow samples, because of inconsistent flowmeter counts and badly damaged specimens, were analyzed qualitatively for species composition by randomly selecting 50 non-damaged specimens from each sample. In all, 54 samples, 36 quantitative and 18 qualitative, were examined.

Table 1. Northeastern Gulf of Mexico station data. S = surface, M = mid-depth, B = bottom.

Station	Date	Position	Bottom Depth (m)	Sampling Times and Duration (min.)	Sampling Depths (m)
M15	6/22/74	29°56′N 088°33′W	25	1647 (15) 1725 (15)	0-7 (S) 4-13 (M) 10-19 (B)
M14	6/22/74	29°56.6′N 088°23.5′W	31	1014 (15) 1053 (15)	0-9 (S) 6-17 (M) 14-25 (B)
M13	6/21/74	29°57′N 088°14′W	31	1706 (15) 1752 (15)	0-9 (S) 6-17 (M) 14-25 (B)
M12	6/18/74	29°46′N 087°54′W	36	1452 (15) 1653 (15)	0-7 (S) 9-18 (M) 20-29 (B)
M11	6/19/74	29°41′N 087°39.5′W	35	1131 (15) 1301 (15)	0-7 (S) 8-17 (M) 18-27 (B)
M10	6/20/74	29°36′N 087°25′W	73	1005 (15) 1147 (15)	0-15 (S) 22-39 (M) 46-63 (B)
C3	6/20/74	29°57′N 087°10′W	55	1852 (60)	0-12 (S) 13-27 (M) 28-42 (B)
C4	6/21/74	29°33′N 088°13′W	43	1043 (60)	0-12 (S) 11-25 (M) 24-38 (B)
A4	6/28/74	29°17′N 087°40′W	364	1829 (60)	0-76 (S) 88-155 (M) 178-256 (B)
A5	6/29/74	29°17′N 088°26′W	62	1028 (60)	0-16 (S) 17-35 (M) 36-54 (B)
A6	6/30/74	29°20′N 088°45′W	49	1210 (60)	0-13 (S) 12-27 (M) 26-41 (B)
A7	6/29/74	28°55′N 088°50′W	348	1910 (60)	0-76 (S) 88-166 (M) 178-256(B)

HYDROGRAPHY OF THE STUDY AREA

Hydrography in the northeastern Gulf of Mexico is characterized by a complex arrangement of salinity, temperature, and density patterns resulting from seasonal interactions of winds, land drainage, tidal influence, and oceanic currents (Drennan 1968). During the summer months, the Loop Current, a branch of the Gulf Stream originating from the Yucatan Straits, dominates Gulf water circulation. With seasonal intensity, the Current protrudes northward into the east-central Gulf, then turns clockwise and exits through the Florida Straits (Leipper 1954). In the area of the present study, a topographically controlled portion of the Loop Current upwelling in the vicinity of the submarine DeSoto Canyon becomes a southwestern drift which flows across the continental shelf south of the Mississippi Sound barrier islands. This drift encounters an eastward-flowing intrusion of low salinity water mainly from the Mississippi River eastern distributaries (Drennan 1968; Christmas and Eleuterius 1973). Salinity and temperature transects through the master stations in June, 1974, are depicted in Figure 2.

RESULTS AND DISCUSSION

The twelve stations sampled in the northeast Gulf of Mexico ranged in depth from 25 to 364 m and displayed a variety of intermixing water types both laterally and vertically. This diverse stratification markedly influenced distribution patterns among the fourteen chaetognath species encountered, each being subject to its own hydrological limits.

Species Observations.
David (1963), in examining the zoogeographic distribution of the chaetognaths, divided the planktonic species into three groups, neritic, mixed water, and oceanic, based on their evolved tolerances to "environmental change", or fluctuating physio-chemical

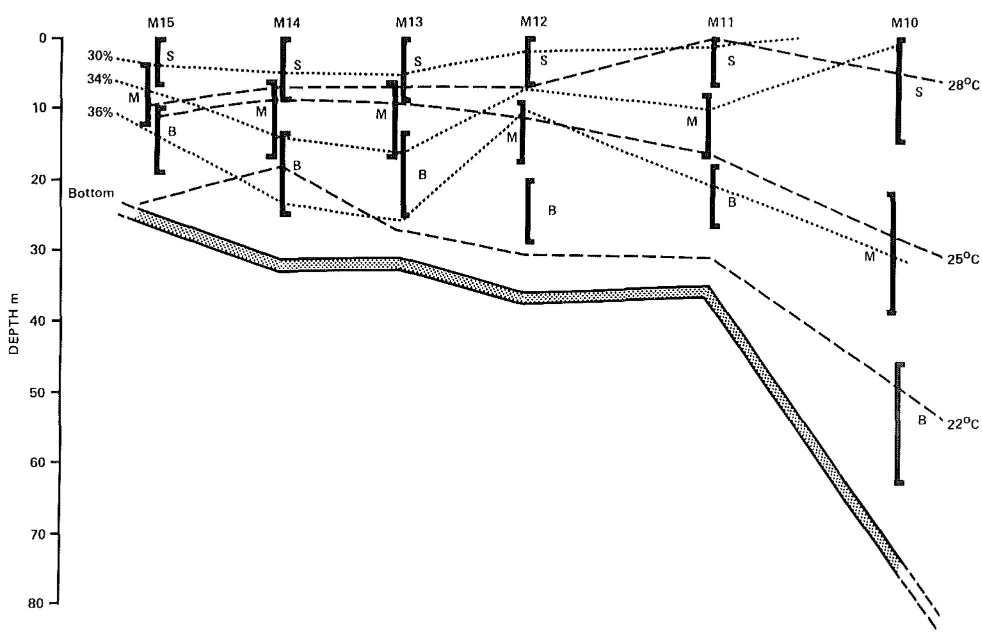

Figure 2. Isohaline and isothermal transects through the master stations in the northeastern Gulf of Mexico. Vertical bars indicate the strata sampled. S = surface, M = mid-depth, B = bottom.

Table 2. Hydrographic ranges of northeastern Gulf of Mexico chaetognaths. Numbers expressed in percent occurrence per range.

Species	Salinity ‰					Temperature °C						Dissolved 0^2 ppm		
	24.9-29.9	30-31.9	32-33.9	34-35.9	36-36.4	14-15.9	16-19.9	20-22.9	23-25.9	26-27.9	28-30.3	2.08-4.99	5.00-6.49	6.50-6.68
Neritic														
Sagitta friderici	20.2	29.8	30.4	17.7	1.9	—	0.3	6.6	21.8	39.2	32.2	1.1	37.9	61.0
S. helenae	—	33.3	33.3	33.3	—	—	—	—	—	100.0	—	—	—	100.0
S. tenuis	11.7	23.6	32.5	28.0	4.2	—	1.9	8.7	18.7	43.6	27.1	0.8	25.5	73.7
S. hispida	0.7	4.4	10.1	44.1	40.7	—	6.7	47.1	18.8	20.0	7.5	35.3	47.2	17.5
Mixed Water														
S. enflata	7.6	13.7	23.7	38.0	17.0	1.0	3.0	15.5	31.0	32.6	16.9	5.9	35.9	58.3
Krohnitta pacifica	3.7	3.7	31.5	44.7	16.5	—	1.6	10.7	21.3	41.2	25.2	1.0	53.7	45.4
Pterosagitta draco	0.4	0.4	0.7	43.1	55.4	2.2	6.6	18.2	35.8	32.5	4.7	6.7	42.3	51.1
S. serratodentata	2.0	2.9	4.8	46.9	43.3	1.6	4.3	20.9	41.2	28.1	3.9	7.3	46.8	45.9
S. minima	1.4	6.4	6.9	36.9	48.4	0.9	11.6	34.7	39.5	9.6	3.6	16.3	65.7	18.0
Oceanic														
S. bipunctata	3.2	3.6	7.5	46.1	39.7	0.7	1.0	26.7	29.6	34.7	7.3	1.1	46.3	52.6
S. hexaptera	—	—	—	20.0	80.0	9.7	30.6	36.8	13.2	9.7	—	20.0	64.9	15.1
K. subtilis	1.0	1.0	6.9	15.8	75.3	14.4	33.9	30.6	11.7	7.2	2.2	38.4	55.2	6.4
S. lyra	—	—	—	—	100.0	8.2	67.4	24.5	—	—	—	43.1	59.9	—
S. decipiens	—	—	—	—	100.0	11.4	67.9	20.7	—	—	—	46.3	56.7	—

conditions, whereby neritic forms are most tolerant and oceanic forms are least tolerant of such changes. Given the degree of distributional overlap among the various species, as reported throughout the literature, David's scheme has been loosely applied here in grouping the fourteen species encountered in this study (Table 2.).

Neritic species, regardless of their wide environmental tolerance, are often localized in their distribution (David 1963). The four neritic species in this study are, concordantly, limited almost exclusively to coastal areas and embayments of the Atlantic Ocean and adjacent seas (Pierce and Wass 1962; Alvarino 1969). In the northeastern Gulf, *Sagitta friderici* and *S. tenuis* shared basically the same habitat, though the latter seemed to be associated with slightly higher salinities and lower temperatures (Table 2). Confusion between these two similar species accounts for the absence of *S. friderici* in prior studies from coastal Atlantic and Gulf waters (McLelland 1980). The notably sporadic occurrence of the neritic forms *S. helenae* and *S. hispida* in what should have been favorable hydrographic conditions was unexpected given their often numerous presence in previous studies of similar coastal environments (Pierce 1951, 1958, 1962). It is likely that the few specimens collected in the study area represented larger inshore populations, or that breeding cycles were at a seasonal minimum for the two species. Reeve (1966) found the breeding season for *S. hispida* in Biscayne Bay, Florida, to be during the cooler months, November to March, followed by a period of summer inactivity.

The five mixed water species are tropico-temperate cosmopolitan forms associated with high salinity water, yet tolerant of coastal regions with fluctuating environmental conditions (Pierce and Wass 1962; David 1963; Alvarino 1965). *Sagitta enflata*, probably the most commonly reported tropical species

Table 3. Chaetognath areal and vertical distribution in the northeastern Gulf of Mexico. S = surface, M = mid-depth, B = bottom.

		Master Stations no./m³*						Alternate and Control Stations % Total no.					
Species	Depth	M15	M14	M13	M12	M11	M10	C3	C4	A4	A5	A6	A7
Sagitta enflata	S	1	14	9	7	16	13	32	59	6	60	28	21
	M	21	20	29	4	69	2	49	67	24	72	37	3
	B	15	4	2	2	7	7	21	27	5	22	19	—
S. friderici	S	33	32	22	4	34	2	41	26	—	6	44	55
	M	4	3	40	1	5	<1	13	—	—	2	2	3
	B	1	1	<1	<1	3	—	5	—	—	2	—	—
S. minima	S	—	3	—	—	—	<1	—	—	5	—	—	6
	M	—	17	8	7	—	<1	—	—	14	5	16	—
	B	—	1	<1	18	10	20	18	—	5	12	55	1
S. tenuis	S	2	5	—	1	6	3	21	9	—	8	22	2
	M	2	<1	1	—	4	<1	4	3	—	—	1	—
	B	—	<1	<1	<1	1	1	—	—	—	—	—	—
S. serratodentata	S	—	—	—	1	—	1	2	2	6	6	3	6
	M	—	<1	2	5	1	2	34	10	15	16	38	10
	B	—	—	—	4	2	2	12	59	5	49	26	1
S. hispida	S	—	—	—	<1	<1	1	5	2	7	8	2	—
	M	—	—	1	<1	—	—	—	—	—	2	—	—
	B	<1	—	—	—	—	1	44	—	—	3	—	—
S. bipunctata	S	—	—	—	—	—	1	—	2	53	6	—	7
	M	—	—	—	<1	—	—	—	10	3	3	—	—
	B	—	—	—	<1	—	<1	—	2	—	—	—	—
S. hexaptera	S	—	—	—	—	—	—	—	—	3	—	—	—
	M	—	—	—	<1	—	<1	—	—	10	—	—	17
	B	—	—	—	—	<1	<1	—	2	—	2	—	1
S. decipiens	S	—	—	—	—	—	—	—	—	—	—	—	—
	M	—	—	—	—	—	—	—	—	14	—	—	39
	B	—	—	—	—	—	—	—	—	60	—	—	74
S. lyra	S	—	—	—	—	—	—	—	—	—	—	—	—
	M	—	—	—	—	—	—	—	—	1	—	—	14
	B	—	—	—	—	—	—	—	—	15	—	—	17
S. helenae	S	—	—	—	—	—	—	—	—	—	—	2	—
	M	—	—	—	—	—	—	—	—	—	—	—	—
	B	—	—	—	—	—	—	—	—	—	—	—	—
Krohnitta pacifica	S	—	—	—	1	1	10	—	—	9	4	—	3
	M	—	—	—	1	3	<1	—	—	—	—	4	—
	B	—	—	<1	<1	<1	<1	—	—	—	2	—	—
K. subtilis	S	—	1	—	<1	—	<1	—	—	2	—	—	—
	M	—	—	—	<1	—	—	—	—	15	—	—	10
	B	—	—	<1	<1	—	1	—	—	10	—	—	7
Pterosagitta draco	S	—	—	—	<1	—	—	—	—	9	—	—	—
	M	—	—	—	1	—	1	—	10	5	—	3	4
	B	—	—	<1	<1	<1	1	—	11	—	9	—	—
Unidentified Juveniles	S	382	235	277	29	56	31						
	M	359	244	137	13	61	4						
	B	179	49	23	20	22	12						
Damaged Specimens	S	30	18	40	4	6	5						
	M	19	15	7	3	8	2						
	B	1	1	1	4	5	2						
Total Chaetognaths	S	448	309	349	46	120	67						
	M	404	299	225	34	150	12						
	B	196	55	27	49	50	46						

*represents replicate means

worldwide, was the most abundant chaetognath in the present study. It differed from the other mixed water species in its marked association with lower salinities (Table 2), and its presence in all samples except at the bottom strata of deep-water station A7 (Table 3). *Sagitta enflata* displayed a mid-depth concentration at stations M15, M14, M13, M11, and, based on percent composition, at C3, C4, and A5 over the continental shelf.

Sagitta minima, third in abundance, concentrated toward deeper, colder water at stations along the continental slope; it occurred in surface collections from only one inshore station, that of M14 (Table 3). Its characteristic association withouter coastal waters of mixed origin, as found in the northeastern Gulf, has limited its value as an indicator of specific water types (Pierce 1953; Owre 1960; Pierce and Wass 1962).

The remaining three mixed water species, *S. serratodentata, Pterosagitta draco*, and *Krohnitta pacifica* have reportedly displayed wide tolerances to changing salinity conditions in temperate and tropical coastal zones (Pierce 1962; Pierce and Wass 1962; David 1963). Almeida-Prado (1968) suggests that, based on its sporadic inshore occurrences, *K. pacifica* might require mixed water for optimal survival conditions. This species occupied a moderately shallow distribution among the Northeast Gulf continental slope stations (Table 3) with densities associated with the 34‰ isohaline. *Sagitta serratodentata* and *P. draco* were similar in their distributions and hydrographic tolerances, although the latter species was less abundant. Both occurred predominantly at the offshore "A" stations but showed evidence of submergence following the downward trend of the 36‰ isohaline toward shore.

The five oceanic species (Table 2) present in this study are cosmopolitan, high salinity forms with characteristically little tolerance for mixed water (David 1963), and are thus, strong indicators of offshore currents. These species are characteristic inhabitants of Florida Current and Gulf Stream waters in the North Atlantic (Bigelow 1926; Owre 1960; Pierce and Wass 1962) and have also been reported in open ocean collections in the Caribbean Sea and Gulf of Mexico (Pierce 1954; Mattlin 1974; Michel and Foyo 1976; Mostajo 1978; Kolesnikov and Alfonso 1966; Every 1968). Mulkana and McIlwain (1973) recorded a brief Mississippi Sound occurrence of *S. hexaptera* and *S. bipunctata* associated with a high salinity peak during the summer months. *Sagitta hexaptera* and *S. bipunctata* are generally considered to be epiplanktonic, *Krohnitta subtilis* transitional from epiplanktonic to mesoplanktonic, and *S. decipens* and *S. lyra* restricted to mesopelagic realms. Among Northeast Gulf stations, *S. hexaptera, S. bipunctata,* and *K. subtilis* displayed similar areal distributions (Table 3) with a marked occurrence at stations along the continental slope (A4, A7) and a scant, submerged appearance at stations over the shelf (M10, M12). These species indicated some degree of vertical separation at the deep water stations A4 and A7; *S. bipunctata* was more prominent in surface samples while *S. hexaptera* and *K. subtilis* maintained a deeper stratification. Their optimal conditions seemed to be in a transition zone between shallow mixed waters and the mesopelagic realm of *S. lyra* and *S. decipiens.*

Population Distribution.

The analysis of master station samples showed a larger inshore and progressively smaller offshore concentration of chaetognaths (Table 3) varying from 448 per m^3 at station M15 surface to 12 per m^3 at the mid-depth of station M10. An inshore abundance of zooplankton is to be expected given the higher rate of primary production normally occurring in areas influenced by nutrient-rich estuarine waters (Raymont 1963). Studies on coastal chaetognath populations from the Florida Straits to Cape Hatteras, North Carolina, revealed similar areal distributions with numbers ranging from two to over a hundred times greater at inshore stations than at adjacent offshore stations (Bumpus and Pierce 1955; Pierce 1958; Pierce and Wass 1962).

Vertically, chaetognaths were more numerous in the upper strata at the inshore stations and more evenly dispersed at the three offshore master stations. This distribution difference was mainly the result of (1) an abundance of juvenile chaetognaths and neritic species predominating in the upper strata inshore and (2) and increased number of oceanic, stenohaline species at the offshore stations.

Maturity Distribution and Spawning Indication.

Juvenile chaetognaths, those showing no ovary or sperm development, comprised the majority of specimens at all master stations (Table 4). Juveniles were concentrated in the upper two-thirds of the water column (S and M) at the three inshore master stations (M15, M14, and M13), but were more evenly dispersed in deeper waters at stations M12, M11, and M10. A tendency toward shallow juvenile distribution has been observed by others and is thought to be associated with shallow-water spawning (Stone 1969). The higher density of juveniles at the inshore stations may be evidence that survival conditions for the newly-hatched individuals are optimal in less-saline, more productive waters.

The population spawning period was estimated by observing the relative proportions of maturity stages present. On this basis, the mixture of maturity stages, and especially the aforementioned disproportionality of juveniles to adults, indicated an early-summer spawn for the population as a whole. Similar population characteristics (i.e., greater juvenile abundance during the summer) were earlier recorded in Mississippi Sound (Perry and Christmas 1973) and in St. Andrew Bay, Florida (Hopkins 1966).

Water Mass Associations.

Water mass interactions in the study area were demonstrated to some extent by species distribution. For example, overlying lower salinity water ranging from 25 to 35‰ was characterized by

Table 4. Chaetognath maturity stages. Vertical distribution at the master stations in no. per m^3. S = surface, M = mid-depth, B = bottom.

		M15	M14	M13	M12	M11	M10
	S	389	249	287	38	71	48
juveniles	M	380	266	170	20	117	8
	B	194	53	31	28	31	25
	S	22	17	12	5	20	6
sub-adults	M	3	14	28	7	11	2
	B	<1	1	<1	10	8	11
	S	8	25	10	4	24	8
adults	M	2	5	16	3	13	1
	B	0	0	<1	8	8	8

the presence of two neritic species, *Sagitta tenuis* and *S. friderici* in upper water levels throughout the study area. Stenohaline species such as *S. serratodentata, S. hexaptera,* and *S. bipunctata* indicated at the outlying stations the presence of oceanic water with salinity greater than 35‰. An intrusion of underlying high salinity water of 33 to 36.3‰ at inshore stations M12, M13, and M14 was evidenced by the occurrence of *S. minima, Krohnitta pacifica,* and *Pterosagitta draco.* These species illustrated Banse's (1964) principle of "brackish water submergence" denoting the occurrence at depth of organisms unable to tolerate lower salinity near the surface.

Station M11, located near the edge of the continental shelf, displayed evidence of a low salinity cell isolated by Loop Current water, possibly an intrusion in the region of M12 (see Fig. 2). Salinities in the upper water column of M11 were lower than those recorded at adjacent stations M10 and M12. Station M11 was distinctly similar to the three inshore master stations in its overall increase in chaetognath numbers and abundance of the neritic species, *S. tenuis* and *S. friderici.* In addition, high salinity species present at adjacent stations M10 and M12 were scarce, if not absent, at station M11.

In the mid-depth and bottom samples (127 m and 217 m) of the deepest outlying, A4 and A7, two oceanic, mesoplanktonic species, *S. decipiens* and *S. lyra* were present. These species, characteristic of deep waters of low temperature and illumination (Owre 1960), were taken in salinities (36.2‰) consistent with the layer of subtropical underwater designated by Nowlin (1971) for the Gulf of Mexico.

All species covered in this work have previously been documented in reports dealing with the distribution and hydrological affinities of Gulf of Mexico chaetognaths. In addition, seven mesobathyplanktonic species have been reported in Gulf waters as follows:

- *Bathybelos typhlops* Owre (Owre 1973; Michel and Foyo 1976)
- *Eukrohnia bathyantarctica* David (Fagetti 1968; Owre 1973; Michel and Foyo 1976)
- *E. bathypelagica* Alvarino (Owre 1973; Michel and Foyo 1976)
- *E. fowleri* Ritter-Zahony (Every 1968; Fagetti 1968)
- *E. hamata* Mobius (Pierce 1954)
- *Sagitta macrocephala* Fowler (Pierce 1954; Every 1968; Fagetti 1968; Owre 1973; Michel and Foyo 1976)
- *S. zetesios* Fowler (Mostajo 1978)

Continuing investigations into deeper regions of the central Gulf will probably extend the range of known species and, as in the case of *B. typhlops*, yield species new to science. As for the northeastern Gulf, extensive work involving seasonal sampling coupled with a detailed study of the hydrography would help to illucidate the dynamics of this most interesting phylum.

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LITERATURE CITED

Almeida-Prado, M. S. de. 1968. Distribution and annual occurrence of Chaetognatha off Canaeia and Santos Coast. *Bol. Inst. Oceanogr.,* Sao Paulo

17(1):33-55.

Alvarino, A. 1965. Chaetognaths. Oceanogr. Mar. Biol. Ann. Rev., 3:115-194.

__________. 1969. Los quetognatos del Atlantico. Distribucion y notas ensenciales de sistematica. *Trab. Inst. Esp. Oceanogr.,* 37, 290 pp.

Banse, K. 1964. On the vertical distribution of zooplankton in the sea. *Progr. in Oceanogr.* 2:53-125.

Bigelow, H. B. 1926. Plankton of the offshore waters of the Gulf of Maine. *Bull. U.S. Bur. Fish.* 40. part 2. 509 pp.

Bumpus, D.F. & E. L. Pierce. 1955. The hydrography and the distribution of chaetognaths over the continental shelf off North Carolina. *Pap. in Mar. Biol. and Oceanogr., Deep Sea Res.* suppl. to 3:92-109.

Christmas, J. Y. & C.K. Eleuterius. 1973. Cooperative Gulf of Mexico Estuarine Inventory and Study, Mississippi. Phase II. Hydrology. publ. Gulf Coast Res. Lab., Ocean Springs, Miss. pp. 73-121.

David, P. M. 1963. Some aspects of speciation in the Chaetognatha. *In:* Speciation in the Sea (Symp.). J. P. Harding & N. Tebble, eds. *Publs. Syst. Assoc.* 5:129-143.

Drennan, K. L. 1968. Hydorgraphic studies in the Northeast Gulf of Mexico. Gulf South Research Inst., Env. Sci. and Eng. Lab., GSRI project NF-170, Rept. No. 68-0-1, New Iberia, LA.

Every, M. G. 1968. The taxonomy and areal distribution of the Chaetognatha in the oceanic Gulf of Mexico. M.S. Thesis. Texas A&M University, College Station. 67 pp.

Fagetti, G.E. 1968. New record of *Eukrohnia bathyantarctica* David, 1958, from the Gulf of Mexico and Caribbean Sea. *Bull. Mar. Sci.* 18(2):383-387.

Hopkins, T.L. 1966. The plankton of the St. Andrew Bay System, Florida. *Contr. Mar. Sci.,* 11:12-64.

Kolesnikov, A.N. & A. Alfonso. 1966. Preliminary data on zooplankton of the eastern part of the Gulf of Mexico and the Florida strait. *In:* Investigations of the Central American Seas. No. I, Kiev., Naukova Dumka Publ. House. [Eng. Trans. Publ. by INSDOC, Delhi-11012, 1973] pp. 141-151.

Leipper, D. F. 1954. Physical oceanography of the Gulf of Mexico. *U.S. Fish Wildl. Serv. Fish. Bull.* 89. 55:119-137.

Maidana, N.I. & E.L. Mostajo. 1980. Fauna de quetognatos de las costas este y oeste de la peninsula de Florida (EE.UU.). Rev. Mus. *Argentina Cienc. Nat. "Bernardino Rivadavia," Inst. Nac. Invest. Cienc. Nat. — Zool.* 12(12):153-160.

Mattlin, R. H., Jr. 1974. Chaetognaths of the Caribbean Sea. M.S. Thesis. Univ. of West Florida, Pensacola. 81 pp.

McLelland, J.A. 1978. The summer distribution of Chaetognatha in the northeastern Gulf of Mexico. M.S. Thesis, Univ. of Southern Miss., Hattiesburg. 173 pp.

__________. 1980. Notes on the northeastern Gulf of Mexico occurrence of *Sagitta friderici* Ritter-Zahony (Chaetognatha). *Gulf Res. Repts.* 6(4):343-348.

Michel, H.B. & M. Foyo. 1976. Caribbean zooplankton. Part 1 — Siphonophora, Heteropoda, Copepoda, Euphausiacea, Chaetognatha and Salpidae. publ. by Office of Nav. Res., Dept. of Nav., U.S. Govt. printing office, Washington D.C., 549 pp.

Mostajo, E.L. 1978. Quetognatos del Mar Caribe y Golfo de Mexico. *Physis* 38(94):47-57.

Mulkana, M.S. & T.D. McIlwain. 1973. The seasonal occurrence and abundance of Chaetognatha in Mississippi Sound. *Gulf Res. Repts.* 4(2):264-271.

Nowlin, W.D. 1971. Water masses and general circulation of the Gulf of Mexico. *Oceanology* 6(2):28-33.

Owre, H.B. 1960. Plankton of the Florida Current. Part VI. The Chaetognatha. *Bull. Mar. Sci.* 10(3):255-322.

__________. 1973. A new chaetognath genus and species with remarks on the taxonomy and distribution of others. *Bull. Mar. Sci.* 23(4):948-963.

Perry, H.M. and J.Y. Christmas. 1973. Cooperative Gulf of Mexico Estuarine Inventory and Study, Mississippi. Phase IV, Section 3. Estuarine Zooplankton, Mississippi. publ. Gulf Coast Res. Lab., Ocean Springs, Miss. pp. 198-254.

Pierce, E.L. 1951. The Chaetognatha of the west coast of Florida. *Biol. Bull. (Woods Hole)* 100:206-228.

__________. 1953. The Chaetognatha over the continental shelf of North Carolina with attention to their relation to the hydrography of the area. *J. Mar. Res.,* 12(1):75-92.

__________. 1954. Notes on the chaetognaths of the Gulf of Mexico. *U.S. Fish Wildl. Serv. Fish. Bull.* 55:227-329.

__________. 1958. The Chaetognatha of the inshore waters of North Carolina. *Limnol. Oceanogr.* 3:166-170.

__________. 1962. Chaetognatha from the Texas coast. *Publ. Inst. Mar. Sci.,* Univ. Texas 8:147-152.

__________ & M.L. Wass. 1962. Chaetognatha from the Florida Current and coastal water of the southeastern Atlantic states. *Bull. Mar. Sci.* 12(3):403-436.

Raymont, J.E.G. 1963. Plankton and productivity in the oceans. *Internat. ser. of Monogr., Pure and Applied Biology.* 18. Pergamon Press. 660 pp.

Reeve, M.R. 1966. Observations on the biology of a chaetognath. *In:* Some contemporary studies in marine science. Harold Barnes, Ed. George Allen and Unwin Ltd., London. pp. 613-630.

Stone, J.H. 1969. The Chaetognatha community of the Agulhas Current: Its structure and related properties. *Ecol. Monogr.* 39:433-463.

Suarez-Caabro, J.A. 1955. Quetognatos de los Mares Cubanos. *Mem. Soc. Cub. Hist. Nat.,* 22(2):125-180.

Tokioka, T. 1955. Notes on some chaetognaths from the Gulf of Mexico. *Bull. Mar. Sci.* 5(1):52-65.

Vega-Rodriguez, F. 1965. Distribution of chaetognatha in Veracruz, Mexico. *Univ. Nac. Autonoma Mex. Inst. Biol. An.* 36(½):229-247.